



dsPIC30F2011/2012/3012/3013

Data Sheet

High-Performance,
16-bit Digital Signal Controllers

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High-Performance, 16-bit Digital Signal Controllers

Note: This data sheet summarizes features of this group of dsPIC30F devices and is not intended to be a complete reference source. For more information on the CPU, peripherals, register descriptions and general device functionality, refer to the “dsPIC30F Family Reference Manual” (DS70046). For more information on the device instruction set and programming, refer to the “16-bit MCU and DSC Programmer’s Reference Manual” (DS70157).

High-Performance Modified RISC CPU:

- Modified Harvard architecture
- C compiler optimized instruction set architecture
- Flexible addressing modes
- 83 base instructions
- 24-bit wide instructions, 16-bit wide data path
- Up to 24 Kbytes on-chip Flash program space
- Up to 2 Kbytes of on-chip data RAM
- Up to 1 Kbytes of nonvolatile data EEPROM
- 16 x 16-bit working register array
- Up to 30 MIPS operation:
 - DC to 40 MHz external clock input
 - 4 MHz - 10 MHz oscillator input with PLL active (4x, 8x, 16x)
- Up to 21 interrupt sources:
 - 8 user-selectable priority levels
 - 3 external interrupt sources
 - 4 processor trap sources

DSP Features:

- Dual data fetch
- Modulo and Bit-Reversed modes
- Two 40-bit wide accumulators with optional saturation logic
- 17-bit x 17-bit single-cycle hardware fractional/integer multiplier
- All DSP instructions are single cycle
 - Multiply-Accumulate (MAC) operation
- Single-cycle ± 16 shift

Peripheral Features:

- High-current sink/source I/O pins: 25 mA/25 mA
- Three 16-bit timers/counters; optionally pair up 16-bit timers into 32-bit timer modules
- 16-bit Capture input functions
- 16-bit Compare/PWM output functions
- 3-wire SPI modules (supports four Frame modes)
- I²C™ module supports Multi-Master/Slave mode and 7-bit/10-bit addressing
- Up to two addressable UART modules with FIFO buffers

Analog Features:

- 12-bit Analog-to-Digital Converter (ADC) with:
 - 200 ksps conversion rate
 - Up to 10 input channels
 - Conversion available during Sleep and Idle
- Programmable Low-Voltage Detection (PLVD)
- Programmable Brown-out Reset

Special Microcontroller Features:

- Enhanced Flash program memory:
 - 10,000 erase/write cycle (min.) for industrial temperature range, 100K (typical)
- Data EEPROM memory:
 - 100,000 erase/write cycle (min.) for industrial temperature range, 1M (typical)
- Self-reprogrammable under software control
- Power-on Reset (POR), Power-up Timer (PWRT) and Oscillator Start-up Timer (OST)
- Flexible Watchdog Timer (WDT) with on-chip low-power RC oscillator for reliable operation
- Fail-Safe Clock Monitor operation:
 - Detects clock failure and switches to on-chip low-power RC oscillator
- Programmable code protection
- In-Circuit Serial Programming™ (ICSP™)
- Selectable Power Management modes:
 - Sleep, Idle and Alternate Clock modes

CMOS Technology:

- Low-power, high-speed Flash technology
- Wide operating voltage range (2.5V to 5.5V)
- Industrial and Extended temperature ranges
- Low-power consumption

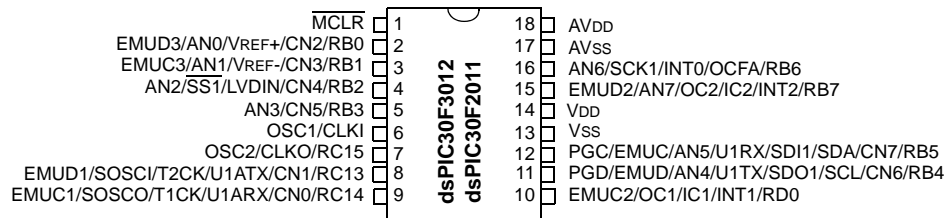
dsPIC30F2011/2012/3012/3013

dsPIC30F2011/2012/3012/3013 Sensor Family

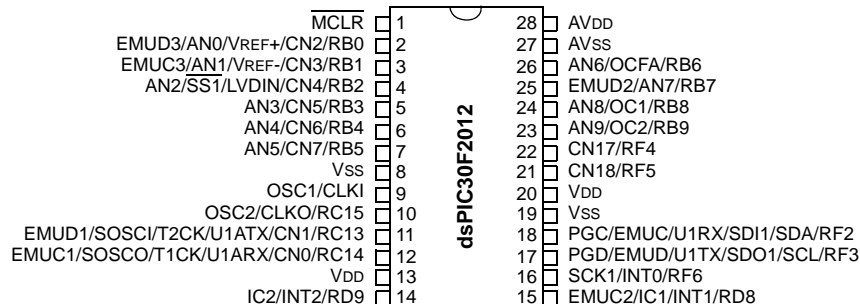
| Device | Pins | Program Memory | | SRAM Bytes | EEPROM Bytes | Timer 16-bit | Input Cap | Output Comp/Std PWM | A/D 12-bit 200 Ksps | UART | SPI | I ² C™ |
|--------------|------|----------------|--------------|------------|--------------|--------------|-----------|---------------------|---------------------|------|-----|-------------------|
| | | Bytes | Instructions | | | | | | | | | |
| dsPIC30F2011 | 18 | 12K | 4K | 1024 | – | 3 | 2 | 2 | 8 ch | 1 | 1 | 1 |
| dsPIC30F3012 | 18 | 24K | 8K | 2048 | 1024 | 3 | 2 | 2 | 8 ch | 1 | 1 | 1 |
| dsPIC30F2012 | 28 | 12K | 4K | 1024 | – | 3 | 2 | 2 | 10 ch | 1 | 1 | 1 |
| dsPIC30F3013 | 28 | 24K | 8K | 2048 | 1024 | 3 | 2 | 2 | 10 ch | 2 | 1 | 1 |

Pin Diagrams

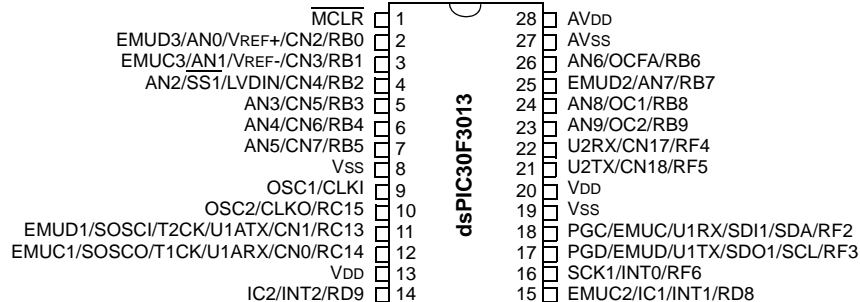
18-Pin PDIP and SOIC



28-Pin PDIP and SOIC



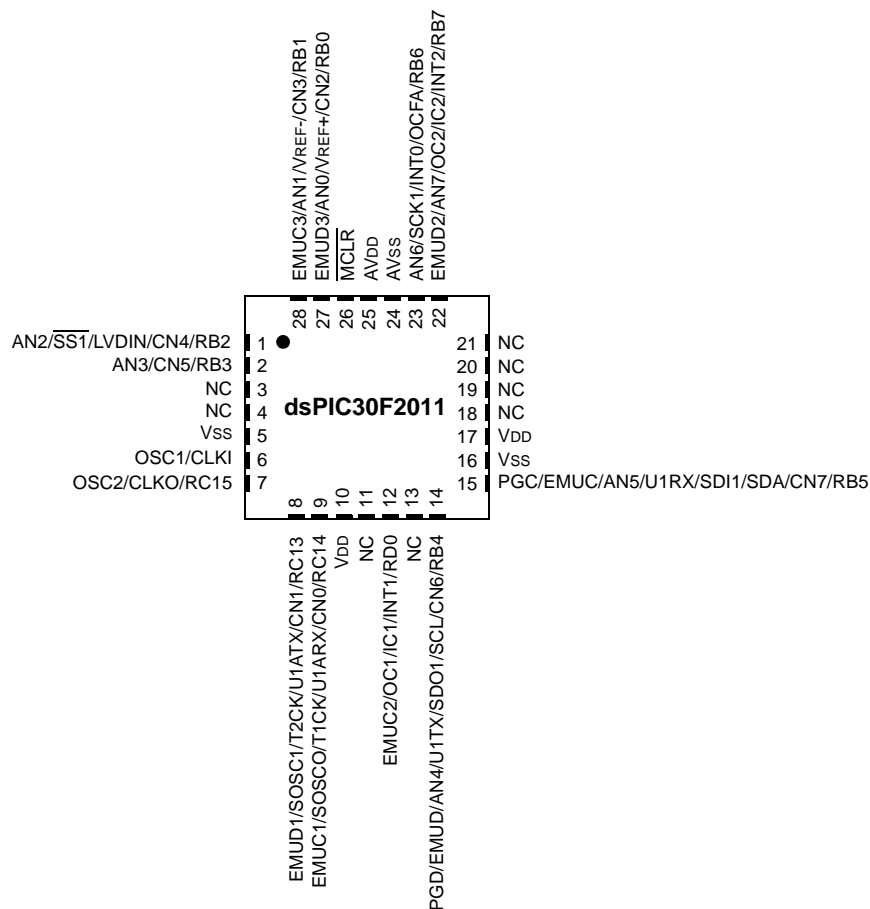
28-Pin SPDIP and SOIC



dsPIC30F2011/2012/3012/3013

Pin Diagrams

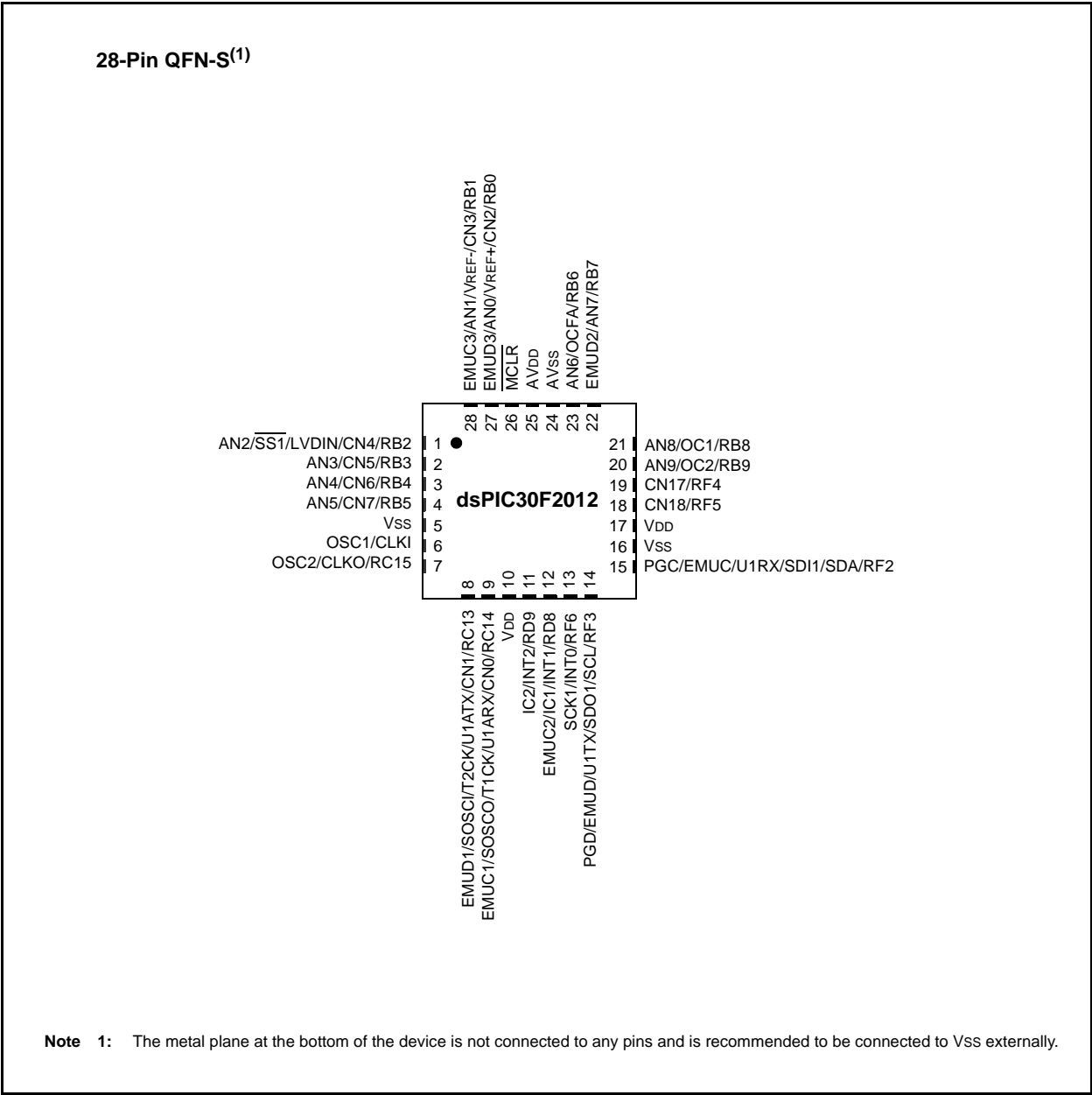
28-Pin QFN-S⁽¹⁾



Note 1: The metal plane at the bottom of the device is not connected to any pins and is recommended to be connected to Vss externally.

dsPIC30F2011/2012/3012/3013

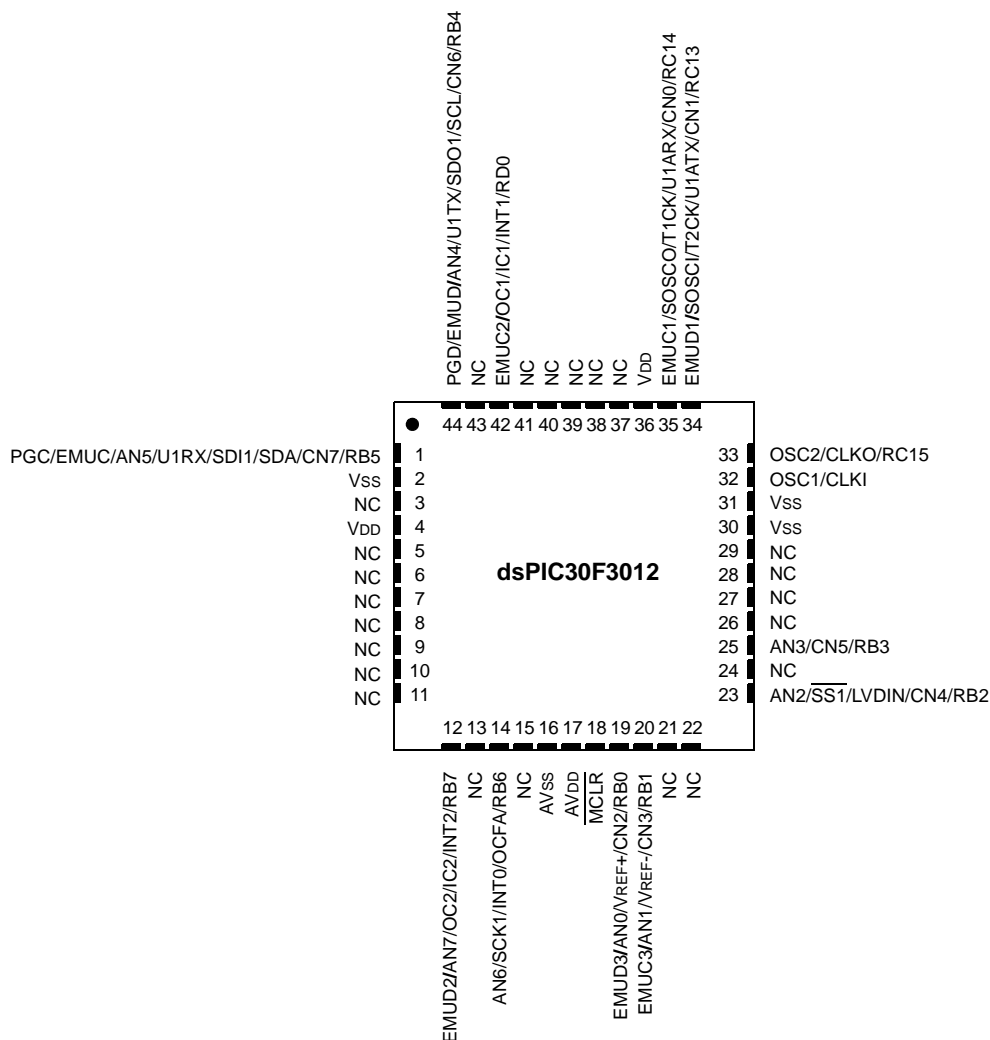
Pin Diagrams



dsPIC30F2011/2012/3012/3013

Pin Diagram

44-Pin QFN⁽¹⁾



Note 1: The metal plane at the bottom of the device is not connected to any pins and is recommended to be connected to Vss externally.

dsPIC30F2011/2012/3012/3013

Pin Diagrams

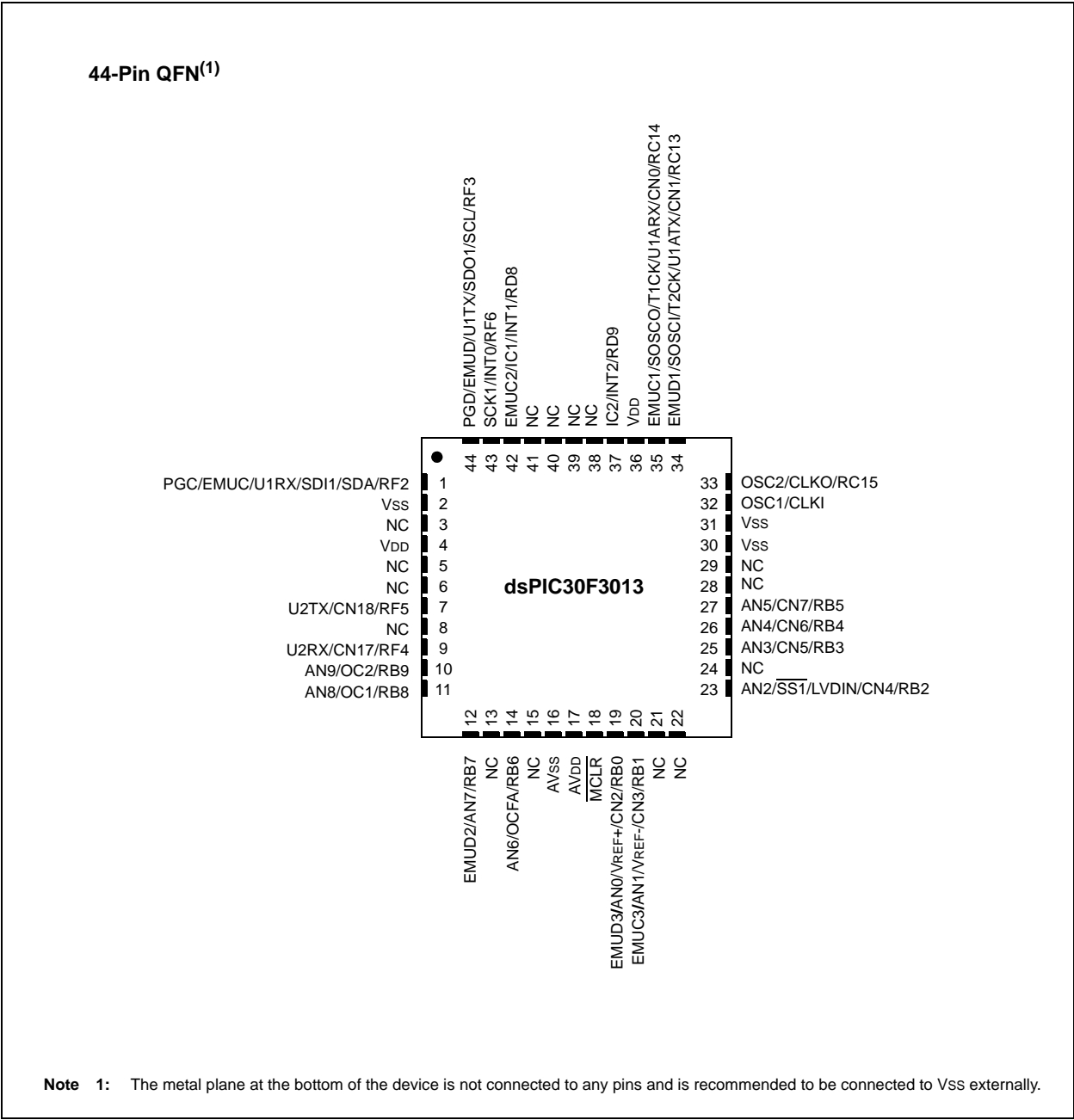


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NOTES:

1.0 DEVICE OVERVIEW

Note: This data sheet summarizes features of this group of dsPIC30F devices and is not intended to be a complete reference source. For more information on the CPU, peripherals, register descriptions and general device functionality, refer to the “*dsPIC30F Family Reference Manual*” (DS70046). For more information on the device instruction set and programming, refer to the “*16-bit MCU and DSC Programmer’s Reference Manual*” (DS70157).

This data sheet contains information specific to the dsPIC30F2011, dsPIC30F2012, dsPIC30F3012 and dsPIC30F3013 Digital Signal Controllers (DSC). These devices contain extensive Digital Signal Processor (DSP) functionality within a high-performance 16-bit microcontroller (MCU) architecture.

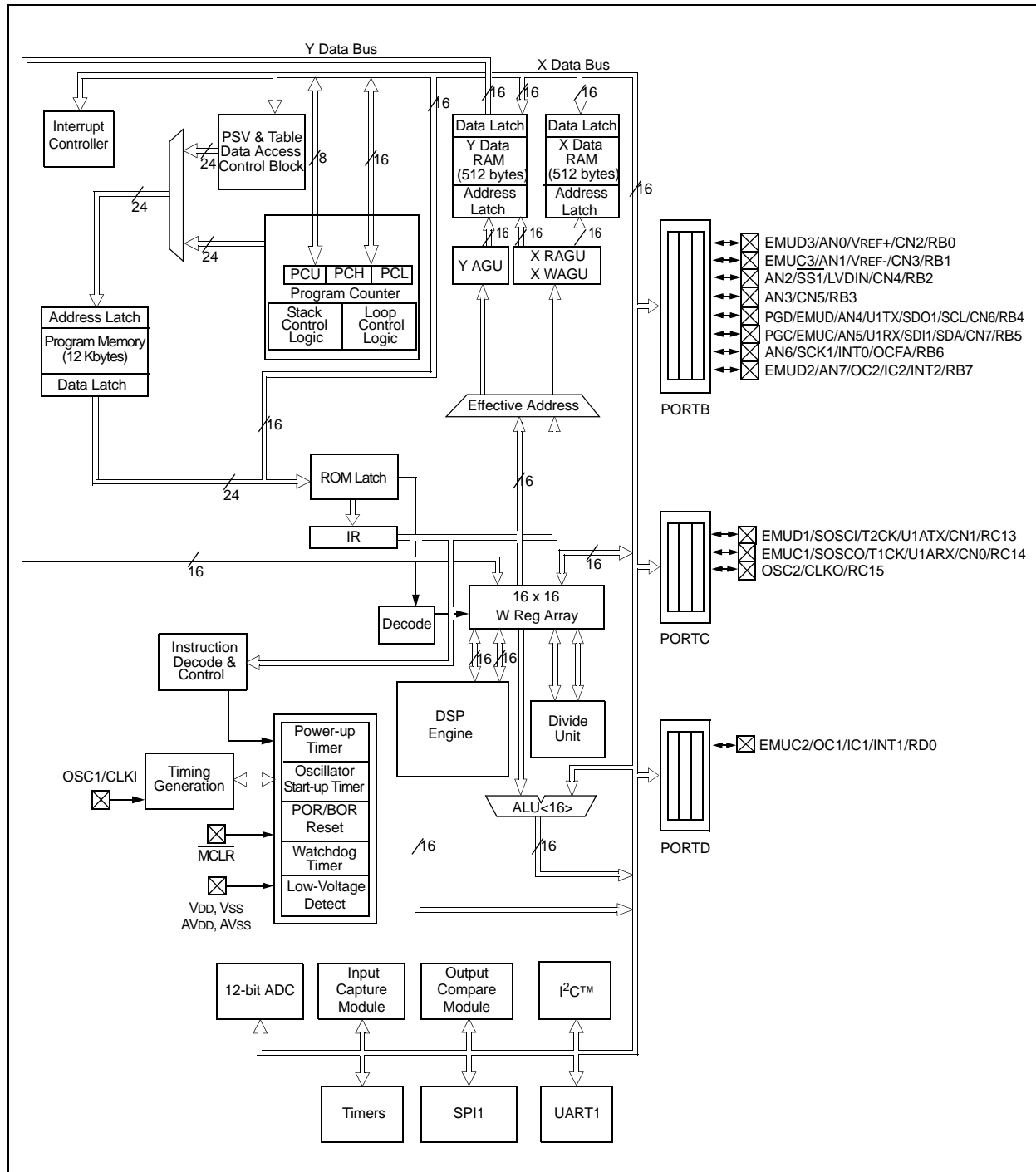
The following block diagrams depict the architecture for these devices:

- [Figure 1-1](#) illustrates the dsPIC30F2011
- [Figure 1-2](#) illustrates the dsPIC30F2012
- [Figure 1-3](#) illustrates the dsPIC30F3012
- [Figure 1-4](#) illustrates the dsPIC30F3013

Following the block diagrams, [Table 1-1](#) relates the I/O functions to pinout information.

dsPIC30F2011/2012/3012/3013

FIGURE 1-1: dsPIC30F2011 BLOCK DIAGRAM





dsPIC30F2011/2012/3012/3013

Table 1-1 provides a brief description of device I/O pinouts and the functions that may be multiplexed to a port pin. Multiple functions may exist on one port pin. When multiplexing occurs, the peripheral module's functional requirements may force an override of the data direction of the port pin.

TABLE 1-1: PINOUT I/O DESCRIPTIONS

| Pin Name | Pin Type | Buffer Type | Description |
|--|--|--|--|
| AN0 - AN9 | I | Analog | Analog input channels. |
| AVDD | P | P | Positive supply for analog module. This pin must be connected at all times. |
| AVSS | P | P | Ground reference for analog module. This pin must be connected at all times. |
| CLKI CLKO | I O | ST/CMOS — | External clock source input. Always associated with OSC1 pin function. Oscillator crystal output. Connects to crystal or resonator in Crystal Oscillator mode. Optionally functions as CLKO in RC and EC modes. Always associated with OSC2 pin function. |
| CN0 - CN7 | I | ST | Input change notification inputs. Can be software programmed for internal weak pull-ups on all inputs. |
| EMUD EMUC EMUD1 EMUC1 EMUD2 EMUC2 EMUD3 EMUC3 | I/O I/O I/O I/O I/O I/O I/O I/O | ST ST ST ST ST ST ST ST | ICD Primary Communication Channel data input/output pin. ICD Primary Communication Channel clock input/output pin. ICD Secondary Communication Channel data input/output pin. ICD Secondary Communication Channel clock input/output pin. ICD Tertiary Communication Channel data input/output pin. ICD Tertiary Communication Channel clock input/output pin. ICD Quaternary Communication Channel data input/output pin. ICD Quaternary Communication Channel clock input/output pin. |
| IC1 - IC2 | I | ST | Capture inputs 1 through 2. |
| INT0 INT1 INT2 | I I I | ST ST ST | External interrupt 0. External interrupt 1. External interrupt 2. |
| LV DIN | I | Analog | Low-Voltage Detect Reference Voltage Input pin. |
| MCLR | I/P | ST | Master Clear (Reset) input or programming voltage input. This pin is an active-low Reset to the device. |
| OC1-OC2 OCFA | O I | — ST | Compare outputs 1 through 2. Compare Fault A input. |
| OSC1 OSC2 | I I/O | ST/CMOS — | Oscillator crystal input. ST buffer when configured in RC mode; CMOS otherwise. Oscillator crystal output. Connects to crystal or resonator in Crystal Oscillator mode. Optionally functions as CLKO in RC and EC modes. |
| PGD PGC | I/O I | ST ST | In-Circuit Serial Programming™ data input/output pin. In-Circuit Serial Programming clock input pin. |
| RB0 - RB9 | I/O | ST | PORTB is a bidirectional I/O port. |
| RC13 - RC15 | I/O | ST | PORTC is a bidirectional I/O port. |
| RD0, RD8-RD9 | I/O | ST | PORTD is a bidirectional I/O port. |
| RF2 - RF5 | I/O | ST | PORTF is a bidirectional I/O port. |
| SCK1 SDI1 SDO1 SS1 | I/O I O I | ST ST — ST | Synchronous serial clock input/output for SPI1. SPI1 Data In. SPI1 Data Out. SPI1 Slave Synchronization. |

Legend: CMOS = CMOS compatible input or output Analog = Analog input
ST = Schmitt Trigger input with CMOS levels O = Output
I = Input P = Power

dsPIC30F2011/2012/3012/3013

TABLE 1-1: PINOUT I/O DESCRIPTIONS (CONTINUED)

| Pin Name | Pin Type | Buffer Type | Description |
|----------|----------|-------------|--|
| SCL | I/O | ST | Synchronous serial clock input/output for I ² C™. |
| SDA | I/O | ST | Synchronous serial data input/output for I ² C. |
| SOSCO | O | — | 32 kHz low-power oscillator crystal output. |
| SOSCI | I | ST/CMOS | 32 kHz low-power oscillator crystal input. ST buffer when configured in RC mode; CMOS otherwise. |
| T1CK | I | ST | Timer1 external clock input. |
| T2CK | I | ST | Timer2 external clock input. |
| U1RX | I | ST | UART1 Receive. |
| U1TX | O | — | UART1 Transmit. |
| U1ARX | I | ST | UART1 Alternate Receive. |
| U1ATX | O | — | UART1 Alternate Transmit. |
| U2RX | I | ST | UART2 Receive. |
| U2TX | O | — | UART2 Transmit. |
| VDD | P | — | Positive supply for logic and I/O pins. |
| VSS | P | — | Ground reference for logic and I/O pins. |
| VREF+ | I | Analog | Analog Voltage Reference (High) input. |
| VREF- | I | Analog | Analog Voltage Reference (Low) input. |

Legend: CMOS = CMOS compatible input or output Analog = Analog input
ST = Schmitt Trigger input with CMOS levels O = Output
I = Input P = Power

NOTES:

2.0 CPU ARCHITECTURE OVERVIEW

Note: This data sheet summarizes features of this group of dsPIC30F devices and is not intended to be a complete reference source. For more information on the CPU, peripherals, register descriptions and general device functionality, refer to the “dsPIC30F Family Reference Manual” (DS70046). For more information on the device instruction set and programming, refer to the “16-bit MCU and DSC Programmer’s Reference Manual” (DS70157).

This section is an overview of the CPU architecture of the dsPIC30F. The core has a 24-bit instruction word. The Program Counter (PC) is 23 bits wide with the Least Significant bit (LSb) always clear (see [Section 3.1 “Program Address Space”](#)). The Most Significant bit (MSb) is ignored during normal program execution, except for certain specialized instructions. Thus, the PC can address up to 4M instruction words of user program space. An instruction prefetch mechanism helps maintain throughput. Program loop constructs, free from loop count management overhead, are supported using the `DO` and `REPEAT` instructions, both of which are interruptible at any point.

2.1 Core Overview

The working register array consists of 16 x 16-bit registers, each of which can act as data, address or offset registers. One working register (W15) operates as a Software Stack Pointer for interrupts and calls.

The data space is 64 Kbytes (32K words) and is split into two blocks, referred to as X and Y data memory. Each block has its own independent Address Generation Unit (AGU). Most instructions operate solely through the X memory, AGU, which provides the appearance of a single unified data space. The Multiply-Accumulate (MAC) class of dual source DSP instructions operate through both the X and Y AGUs, splitting the data address space into two parts (see [Section 3.2 “Data Address Space”](#)). The X and Y data space boundary is device specific and cannot be altered by the user. Each data word consists of 2 bytes and most instructions can address data either as words or bytes.

Two ways to access data in program memory are:

- The upper 32 Kbytes of data space memory can be mapped into the lower half (user space) of program space at any 16K program word boundary, defined by the 8-bit Program Space Visibility Page register (PSVPAG). Thus any instruction can access program space as if it were data space, with a limitation that the access requires an additional cycle. Only the lower 16 bits of each instruction word can be accessed using this method.
- Linear indirect access of 32K word pages within program space is also possible using any working register, via table read and write instructions. Table read and write instructions can be used to access all 24 bits of an instruction word.

Overhead-free circular buffers (Modulo Addressing) are supported in both X and Y address spaces. This is primarily intended to remove the loop overhead for DSP algorithms.

The X AGU also supports Bit-Reversed Addressing on destination effective addresses to greatly simplify input or output data reordering for radix-2 FFT algorithms. Refer to [Section 4.0 “Address Generator Units”](#) for details on Modulo and Bit-Reversed Addressing.

The core supports Inherent (no operand), Relative, Literal, Memory Direct, Register Direct, Register Indirect, Register Offset and Literal Offset Addressing modes. Instructions are associated with pre-defined addressing modes, depending upon their functional requirements.

For most instructions, the core is capable of executing a data (or program data) memory read, a working register (data) read, a data memory write and a program (instruction) memory read per instruction cycle. As a result, 3 operand instructions are supported, allowing $C = A+B$ operations to be executed in a single cycle.

A DSP engine has been included to significantly enhance the core arithmetic capability and throughput. It features a high-speed 17-bit by 17-bit multiplier, a 40-bit ALU, two 40-bit saturating accumulators and a 40-bit bidirectional barrel shifter. Data in the accumulator or any working register can be shifted up to 15 bits right, or 16 bits left in a single cycle. The DSP instructions operate seamlessly with all other instructions and have been designed for optimal real-time performance. The MAC class of instructions can concurrently fetch two data operands from memory while multiplying two W registers. To enable this concurrent fetching of data operands, the data space has been split for these instructions and linear is for all others. This has been achieved in a transparent and flexible manner, by dedicating certain working registers to each address space for the MAC class of instructions.

The core does not support a multi-stage instruction pipeline. However, a single-stage instruction prefetch mechanism is used, which accesses and partially decodes instructions a cycle ahead of execution, in order to maximize available execution time. Most instructions execute in a single cycle with certain exceptions.

The core features a vectored exception processing structure for traps and interrupts, with 62 independent vectors. The exceptions consist of up to 8 traps (of which 4 are reserved) and 54 interrupts. Each interrupt is prioritized based on a user-assigned priority between 1 and 7 (1 being the lowest priority and 7 being the highest), in conjunction with a predetermined 'natural order'. Traps have fixed priorities ranging from 8 to 15.

2.2 Programmer's Model

The programmer's model is shown in [Figure 2-1](#) and consists of 16 x 16-bit working registers (W0 through W15), 2 x 40-bit accumulators (ACCA and ACCB), STATUS register (SR), Data Table Page register (TBLPAG), Program Space Visibility Page register (PSVPAG), DO and REPEAT registers (DOSTART, DOEND, DCOUNT and RCOUNT) and Program Counter (PC). The working registers can act as data, address or offset registers. All registers are memory mapped. W0 acts as the W register for file register addressing.

Some of these registers have a shadow register associated with each of them, as shown in [Figure 2-1](#). The shadow register is used as a temporary holding register and can transfer its contents to or from its host register upon the occurrence of an event. None of the shadow registers are accessible directly. The following rules apply for transfer of registers into and out of shadows.

- `PUSH.S` and `POP.S`
W0, W1, W2, W3, SR (DC, N, OV, Z and C bits only) are transferred.
- DO instruction
DOSTART, DOEND, DCOUNT shadows are pushed on loop start and popped on loop end.

When a byte operation is performed on a working register, only the Least Significant Byte (LSB) of the target register is affected. However, a benefit of memory mapped working registers is that both the Least and Most Significant Bytes (MSB) can be manipulated through byte-wide data memory space accesses.

2.2.1 SOFTWARE STACK POINTER/ FRAME POINTER

The dsPIC[®] DSC devices contain a software stack. W15 is the dedicated Software Stack Pointer (SP), which is automatically modified by exception processing and subroutine calls and returns. However, W15 can be referenced by any instruction in the same manner as all other W registers. This simplifies the reading, writing and manipulation of the Stack Pointer (e.g., creating stack frames).

Note: In order to protect against misaligned stack accesses, W15<0> is always clear.

W15 is initialized to 0x0800 during a Reset. The user may reprogram the SP during initialization to any location within data space.

W14 has been dedicated as a Stack Frame Pointer, as defined by the `LNK` and `ULNK` instructions. However, W14 can be referenced by any instruction in the same manner as all other W registers.

2.2.2 STATUS REGISTER

The dsPIC DSC core has a 16-bit STATUS register (SR), the LSB of which is referred to as the SR Low byte (SRL) and the MSB as the SR High byte (SRH). See [Figure 2-1](#) for SR layout.

SRL contains all the MCU ALU operation Status flags (including the Z bit), as well as the CPU Interrupt Priority Level Status bits, IPL<2:0>, and the Repeat Active Status bit, RA. During exception processing, SRL is concatenated with the MSB of the PC to form a complete word value which is then stacked.

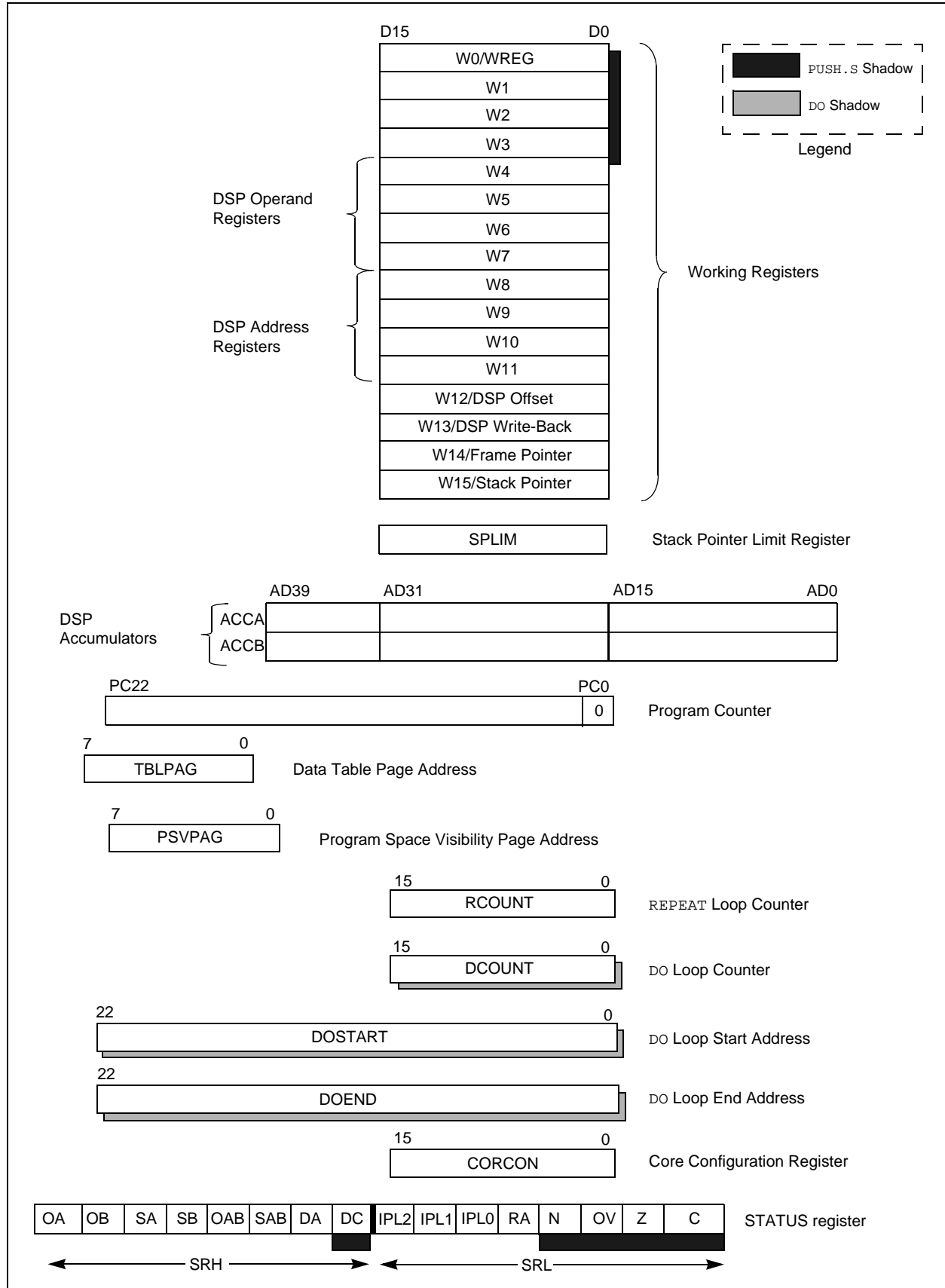
The upper byte of the STATUS register contains the DSP Adder/Subtractor Status bits, the DO Loop Active bit (DA) and the Digit Carry (DC) Status bit.

2.2.3 PROGRAM COUNTER

The program counter is 23 bits wide; bit 0 is always clear. Therefore, the PC can address up to 4M instruction words.

dsPIC30F2011/2012/3012/3013

FIGURE 2-1: PROGRAMMER'S MODEL



2.3 Divide Support

The dsPIC DSC devices feature a 16/16-bit signed fractional divide operation, as well as 32/16-bit and 16/16-bit signed and unsigned integer divide operations, in the form of single instruction iterative divides. The following instructions and data sizes are supported:

1. `DIVF` - 16/16 signed fractional divide
2. `DIV.sd` - 32/16 signed divide
3. `DIV.ud` - 32/16 unsigned divide
4. `DIV.s` - 16/16 signed divide
5. `DIV.u` - 16/16 unsigned divide

The 16/16 divides are similar to the 32/16 (same number of iterations), but the dividend is either zero-extended or sign-extended during the first iteration.

The divide instructions must be executed within a `REPEAT` loop. Any other form of execution (e.g., a series of discrete divide instructions) will not function correctly because the instruction flow depends on `RCOUNT`. The divide instruction does not automatically set up the `RCOUNT` value and it must, therefore, be explicitly and correctly specified in the `REPEAT` instruction, as shown in [Table 2-1](#) (`REPEAT` executes the target instruction {operand value+1} times). The `REPEAT` loop count must be setup for 18 iterations of the `DIV/DIVF` instruction. Thus, a complete divide operation requires 19 cycles.

Note: The divide flow is interruptible; however, the user needs to save the context as appropriate.

TABLE 2-1: DIVIDE INSTRUCTIONS

| Instruction | Function |
|---------------------|---|
| <code>DIVF</code> | Signed fractional divide: $Wm/Wn \rightarrow W0$; $Rem \rightarrow W1$ |
| <code>DIV.sd</code> | Signed divide: $(Wm+1:Wm)/Wn \rightarrow W0$; $Rem \rightarrow W1$ |
| <code>DIV.s</code> | Signed divide: $Wm/Wn \rightarrow W0$; $Rem \rightarrow W1$ |
| <code>DIV.ud</code> | Unsigned divide: $(Wm+1:Wm)/Wn \rightarrow W0$; $Rem \rightarrow W1$ |
| <code>DIV.u</code> | Unsigned divide: $Wm/Wn \rightarrow W0$; $Rem \rightarrow W1$ |

2.4 DSP Engine

The DSP engine consists of a high-speed 17-bit x 17-bit multiplier, a barrel shifter and a 40-bit adder/subtractor (with two target accumulators, round and saturation logic).

The DSP engine also has the capability to perform inherent accumulator-to-accumulator operations, which require no additional data. These instructions are ADD, SUB and NEG.

The dsPIC30F is a single-cycle instruction flow architecture, therefore, concurrent operation of the DSP engine with MCU instruction flow is not possible. However, some MCU ALU and DSP engine resources may be used concurrently by the same instruction (e.g., ED, EDAC). See [Table 2-2](#).

The DSP engine has several options selected through various bits in the CPU Core Configuration register (CORCON), which are:

1. Fractional or integer DSP multiply (IF).
2. Signed or unsigned DSP multiply (US).
3. Conventional or convergent rounding (RND).
4. Automatic saturation on/off for ACCA (SATA).
5. Automatic saturation on/off for ACCB (SATB).
6. Automatic saturation on/off for writes to data memory (SATDW).
7. Accumulator Saturation mode selection (ACCSAT).

Note: For CORCON layout, see [Table 3-3](#).

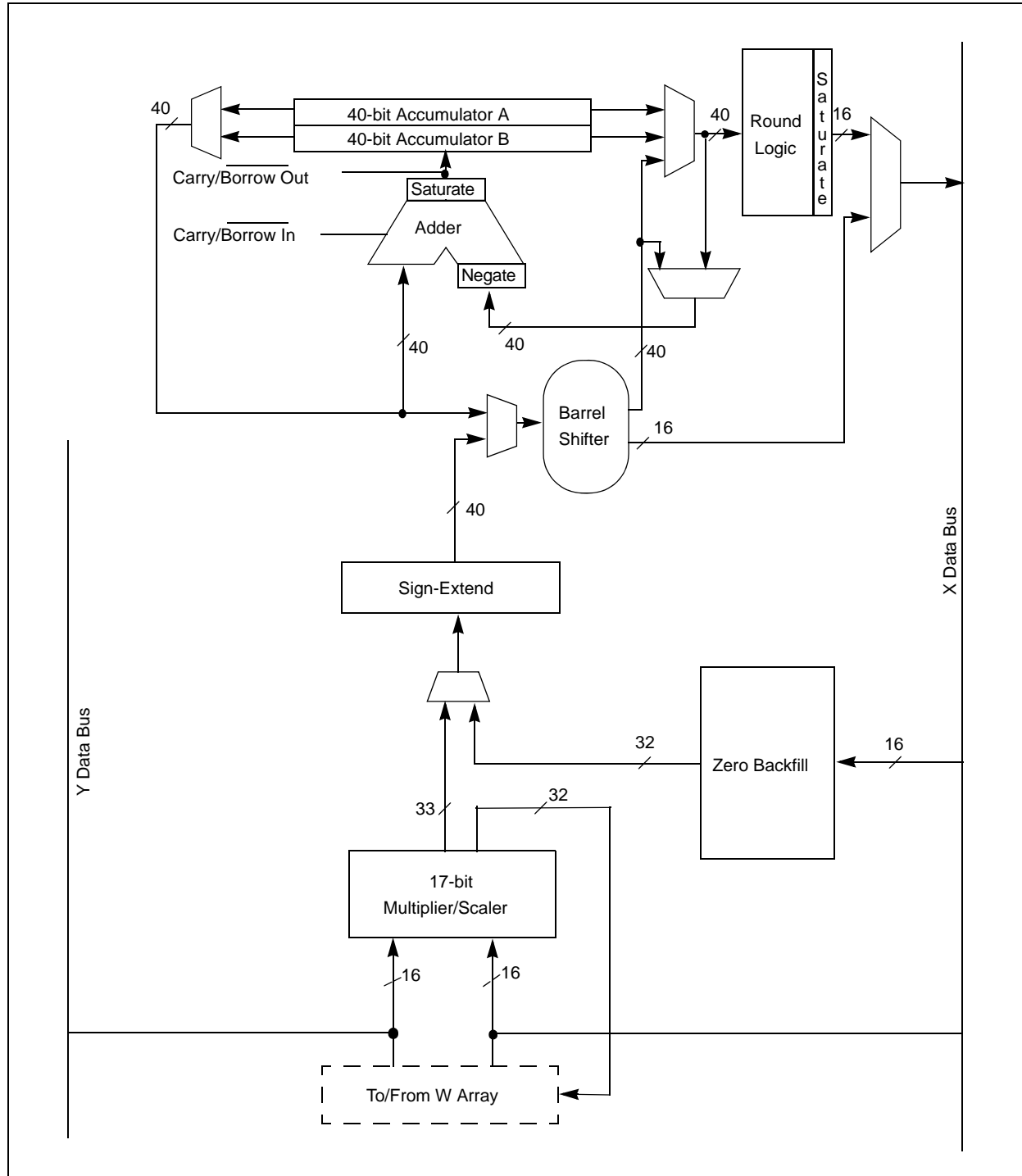
A block diagram of the DSP engine is shown in [Figure 2-2](#).

TABLE 2-2: DSP INSTRUCTION SUMMARY

| Instruction | Algebraic Operation | ACC WB? |
|-------------|---------------------|---------|
| CLR | $A = 0$ | Yes |
| ED | $A = (x - y)^2$ | No |
| EDAC | $A = A + (x - y)^2$ | No |
| MAC | $A = A + (x * y)$ | Yes |
| MAC | $A = A + x^2$ | No |
| MOVSAC | No change in A | Yes |
| MPY | $A = x * y$ | No |
| MPY.N | $A = -x * y$ | No |
| MSC | $A = A - x * y$ | Yes |

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FIGURE 2-2: DSP ENGINE BLOCK DIAGRAM



2.4.1 MULTIPLIER

The 17 x 17-bit multiplier is capable of signed or unsigned operation and can multiplex its output using a scaler to support either 1.31 fractional (Q31) or 32-bit integer results. Unsigned operands are zero-extended into the 17th bit of the multiplier input value. Signed operands are sign-extended into the 17th bit of the multiplier input value. The output of the 17 x 17-bit multiplier/scaler is a 33-bit value which is sign-extended to 40 bits. Integer data is inherently represented as a signed two's complement value, where the MSB is defined as a sign bit. Generally speaking, the range of an N-bit two's complement integer is -2^{N-1} to $2^{N-1} - 1$. For a 16-bit integer, the data range is -32768 (0x8000) to 32767 (0x7FFF) including '0'. For a 32-bit integer, the data range is -2,147,483,648 (0x8000 0000) to 2,147,483,645 (0x7FFF FFFF).

When the multiplier is configured for fractional multiplication, the data is represented as a two's complement fraction, where the MSB is defined as a sign bit and the radix point is implied to lie just after the sign bit (QX format). The range of an N-bit two's complement fraction with this implied radix point is -1.0 to $(1 - 2^{1-N})$. For a 16-bit fraction, the Q15 data range is -1.0 (0x8000) to 0.999969482 (0x7FFF) including '0' and has a precision of 3.01518×10^{-5} . In Fractional mode, the 16x16 multiply operation generates a 1.31 product, which has a precision of 4.65661×10^{-10} .

The same multiplier is used to support the MCU multiply instructions, which include integer 16-bit signed, unsigned and mixed sign multiplies.

The MUL instruction can be directed to use byte or word-sized operands. Byte operands direct a 16-bit result. Word operands direct a 32-bit result to the specified register(s) in the W array.

2.4.2 DATA ACCUMULATORS AND ADDER/SUBTRACTER

The data accumulator consists of a 40-bit adder/subtractor with automatic sign extension logic. It can select one of two accumulators (A or B) as its pre-accumulation source and post-accumulation destination. For the ADD and LAC instructions, the data to be accumulated or loaded can be optionally scaled through the barrel shifter prior to accumulation.

2.4.2.1 Adder/Subtractor, Overflow and Saturation

The adder/subtractor is a 40-bit adder with an optional zero input into one side and either true or complement data into the other input. In the case of addition, the carry/borrow input is active high and the other input is true data (not complemented), whereas in the case of subtraction, the carry/borrow input is active low and the other input is complemented. The adder/subtractor generates overflow status bits SA/SB and OA/OB, which are latched and reflected in the STATUS register:

- Overflow from bit 39: This is a catastrophic overflow in which the sign of the accumulator is destroyed.
- Overflow into guard bits 32 through 39: This is a recoverable overflow. This bit is set whenever all the guard bits are not identical to each other.

The adder has an additional saturation block which controls accumulator data saturation if selected. It uses the result of the adder, the overflow Status bits described above, and the mode control bits SATA/B (CORCON<7:6>) and ACCSAT (CORCON<4>) to determine when and to what value to saturate.

Six STATUS register bits have been provided to support saturation and overflow. They are:

- OA: ACCA overflowed into guard bits
- OB: ACCB overflowed into guard bits
- SA: ACCA saturated (bit 31 overflow and saturation)
or
ACCA overflowed into guard bits and saturated (bit 39 overflow and saturation)
- SB: ACCB saturated (bit 31 overflow and saturation)
or
ACCB overflowed into guard bits and saturated (bit 39 overflow and saturation)
- OAB: Logical OR of OA and OB
- SAB: Logical OR of SA and SB

The OA and OB bits are modified each time data passes through the adder/subtractor. When set, they indicate that the most recent operation has overflowed into the accumulator guard bits (bits 32 through 39). The OA and OB bits can also optionally generate an arithmetic warning trap when set and the corresponding overflow trap flag enable bit (OVATE, OVATE) in the INTCON1 register (refer to [Section 8.0 "Interrupts"](#)) is set. This allows the user to take immediate action, for example, to correct system gain.

The SA and SB bits are modified each time data passes through the adder/subtractor but can only be cleared by the user. When set, they indicate that the accumulator has overflowed its maximum range (bit 31 for 32-bit saturation or bit 39 for 40-bit saturation) and will be saturated if saturation is enabled. When saturation is not enabled, SA and SB default to bit 39 overflow and thus indicate that a catastrophic overflow has occurred. If the COVTE bit in the INTCON1 register is set, SA and SB bits generate an arithmetic warning trap when saturation is disabled.

The overflow and saturation Status bits can optionally be viewed in the STATUS register (SR) as the logical OR of OA and OB (in bit OAB) and the logical OR of SA and SB (in bit SAB). This allows programmers to check one bit in the STATUS register to determine if either accumulator has overflowed, or one bit to determine if either accumulator has saturated. This would be useful for complex number arithmetic which typically uses both the accumulators.

The device supports three saturation and overflow modes:

1. **Bit 39 Overflow and Saturation:**
When bit 39 overflow and saturation occurs, the saturation logic loads the maximally positive 9.31 (0x7FFFFFFF) or maximally negative 9.31 value (0x80000000) into the target accumulator. The SA or SB bit is set and remains set until cleared by the user. This is referred to as 'super saturation' and provides protection against erroneous data or unexpected algorithm problems (e.g., gain calculations).
2. **Bit 31 Overflow and Saturation:**
When bit 31 overflow and saturation occurs, the saturation logic then loads the maximally positive 1.31 value (0x007FFFFFFF) or maximally negative 1.31 value (0x0080000000) into the target accumulator. The SA or SB bit is set and remains set until cleared by the user. When this Saturation mode is in effect, the guard bits are not used, so the OA, OB or OAB bits are never set.
3. **Bit 39 Catastrophic Overflow:**
The bit 39 overflow Status bit from the adder is used to set the SA or SB bit which remains set until cleared by the user. No saturation operation is performed and the accumulator is allowed to overflow (destroying its sign). If the COVTE bit in the INTCON1 register is set, a catastrophic overflow can initiate a trap exception.

2.4.2.2 Accumulator 'Write-Back'

The MAC class of instructions (with the exception of MPY, MPY.N, ED and EDAC) can optionally write a rounded version of the high word (bits 31 through 16) of the accumulator that is not targeted by the instruction into data space memory. The write is performed across the X bus into combined X and Y address space. The following addressing modes are supported:

1. **W13, Register Direct:**
The rounded contents of the non-target accumulator are written into W13 as a 1.15 fraction.
2. **[W13]+ = 2, Register Indirect with Post-Increment:**
The rounded contents of the non-target accumulator are written into the address pointed to by W13 as a 1.15 fraction. W13 is then incremented by 2 (for a word write).

2.4.2.3 Round Logic

The round logic is a combinational block which performs a conventional (biased) or convergent (unbiased) round function during an accumulator write (store). The Round mode is determined by the state of the RND bit in the CORCON register. It generates a 16-bit, 1.15 data value, which is passed to the data space write saturation logic. If rounding is not indicated by the instruction, a truncated 1.15 data value is stored and the least significant word (lsw) is simply discarded.

Conventional rounding takes bit 15 of the accumulator, zero-extends it and adds it to the ACCxH word (bits 16 through 31 of the accumulator). If the ACCxL word (bits 0 through 15 of the accumulator) is between 0x8000 and 0xFFFF (0x8000 included), ACCxH is incremented. If ACCxL is between 0x0000 and 0x7FFF, ACCxH is left unchanged. A consequence of this algorithm is that over a succession of random rounding operations, the value tends to be biased slightly positive.

Convergent (or unbiased) rounding operates in the same manner as conventional rounding, except when ACCxL equals 0x8000. If this is the case, the LSB (bit 16 of the accumulator) of ACCxH is examined. If it is '1', ACCxH is incremented. If it is '0', ACCxH is not modified. Assuming that bit 16 is effectively random in nature, this scheme will remove any rounding bias that may accumulate.

The SAC and SAC.R instructions store either a truncated (SAC) or rounded (SAC.R) version of the contents of the target accumulator to data memory via the X bus (subject to data saturation, see [Section 2.4.2.4 "Data Space Write Saturation"](#)). Note that for the MAC class of instructions, the accumulator write-back operation functions in the same manner, addressing combined MCU (X and Y) data space though the X bus. For this class of instructions, the data is always subject to rounding.

2.4.2.4 Data Space Write Saturation

In addition to adder/subtractor saturation, writes to data space may also be saturated but without affecting the contents of the source accumulator. The data space write saturation logic block accepts a 16-bit, 1.15 fractional value from the round logic block as its input, together with overflow status from the original source (accumulator) and the 16-bit round adder. These are combined and used to select the appropriate 1.15 fractional value as output to write to data space memory.

If the SATDW bit in the CORCON register is set, data (after rounding or truncation) is tested for overflow and adjusted accordingly. For input data greater than 0x007FFF, data written to memory is forced to the maximum positive 1.15 value, 0x7FFF. For input data less than 0xFF8000, data written to memory is forced to the maximum negative 1.15 value, 0x8000. The MSb of the source (bit 39) is used to determine the sign of the operand being tested.

If the SATDW bit in the CORCON register is not set, the input data is always passed through unmodified under all conditions.

2.4.3 BARREL SHIFTER

The barrel shifter is capable of performing up to 16-bit arithmetic or logic right shifts, or up to 16-bit left shifts in a single cycle. The source can be either of the two DSP accumulators, or the X bus (to support multi-bit shifts of register or memory data).

The shifter requires a signed binary value to determine both the magnitude (number of bits) and direction of the shift operation. A positive value shifts the operand right. A negative value shifts the operand left. A value of '0' does not modify the operand.

The barrel shifter is 40 bits wide, thereby obtaining a 40-bit result for DSP shift operations and a 16-bit result for MCU shift operations. Data from the X bus is presented to the barrel shifter between bit positions 16 to 31 for right shifts, and bit positions 0 to 16 for left shifts.

NOTES:

3.0 MEMORY ORGANIZATION

Note: This data sheet summarizes features of this group of dsPIC30F devices and is not intended to be a complete reference source. For more information on the CPU, peripherals, register descriptions and general device functionality, refer to the “*dsPIC30F Family Reference Manual*” (DS70046). For more information on the device instruction set and programming, refer to the “*16-bit MCU and DSC Programmer’s Reference Manual*” (DS70157).

3.1 Program Address Space

The program address space is 4M instruction words. The program space memory maps for the dsPIC30F2011/2012/3012/3013 devices is shown in [Figure 3-1](#).

Program memory is addressable by a 24-bit value from either the 23-bit PC, table instruction Effective Address (EA), or data space EA, when program space is mapped into data space as defined by [Table 3-1](#). Note that the program space address is incremented by two between successive program words in order to provide compatibility with data space addressing.

User program space access is restricted to the lower 4M instruction word address range (0x000000 to 0x7FFFFE) for all accesses other than TBLRD/TBLWT, which uses TBLPAG<7> to determine user or configuration space access. In [Table 3-1](#), Program Space Address Construction, bit 23 allows access to the Device ID, the User ID and the Configuration bits. Otherwise, bit 23 is always clear.

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FIGURE 3-1: PROGRAM SPACE MEMORY MAPS

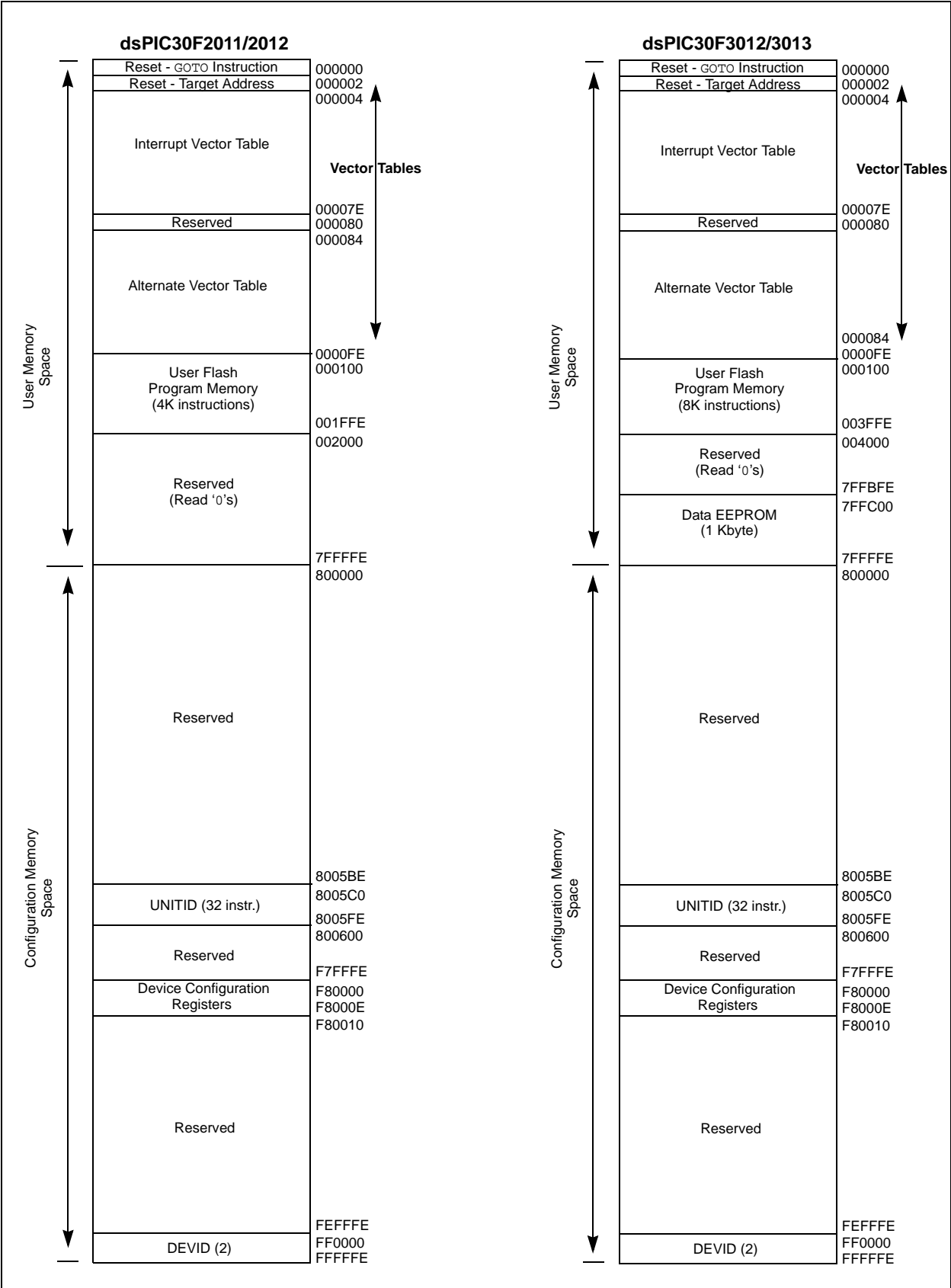
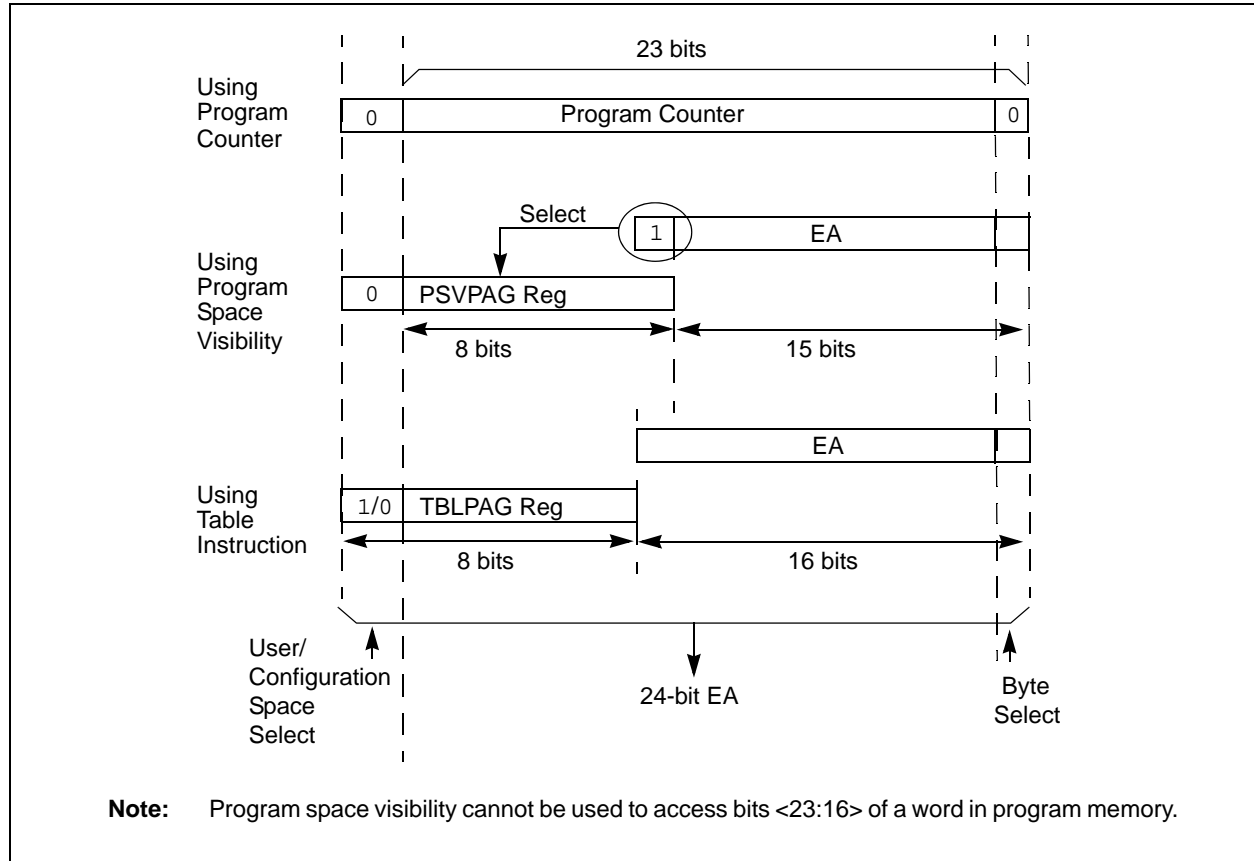


TABLE 3-1: PROGRAM SPACE ADDRESS CONSTRUCTION

| Access Type | Access Space | Program Space Address | | | | |
|--------------------------|----------------------------------|-----------------------|-------------|------|---------------|-----|
| | | <23> | <22:16> | <15> | <14:1> | <0> |
| Instruction Access | User | 0 | PC<22:1> | | | 0 |
| TBLRD/TBLWT | User (TBLPAG<7> = 0) | TBLPAG<7:0> | | | Data EA<15:0> | |
| TBLRD/TBLWT | Configuration (TBLPAG<7> = 1) | TBLPAG<7:0> | | | Data EA<15:0> | |
| Program Space Visibility | User | 0 | PSVPAG<7:0> | | Data EA<14:0> | |

FIGURE 3-2: DATA ACCESS FROM PROGRAM SPACE ADDRESS GENERATION



3.1.1 DATA ACCESS FROM PROGRAM MEMORY USING TABLE INSTRUCTIONS

This architecture fetches 24-bit wide program memory. Consequently, instructions are always aligned. However, as the architecture is modified Harvard, data can also be present in program space.

There are two methods by which program space can be accessed: via special table instructions, or through the remapping of a 16K word program space page into the upper half of data space (see [Section 3.1.2 “Data Access from Program Memory Using Program Space Visibility”](#)). The TBLRDL and TBLWTL instructions offer a direct method of reading or writing the lsw of any address within program space, without going through data space. The TBLRDH and TBLWTH instructions are the only method whereby the upper 8 bits of a program space word can be accessed as data.

The PC is incremented by two for each successive 24-bit program word. This allows program memory addresses to directly map to data space addresses. Program memory can thus be regarded as two 16-bit word wide address spaces, residing side by side, each with the same address range. TBLRDL and TBLWTL access the space which contains the lsw, and TBLRDH and TBLWTH access the space which contains the MSB.

[Figure 3-2](#) shows how the EA is created for table operations and data space accesses (PSV = 1). Here, P<23:0> refers to a program space word, whereas D<15:0> refers to a data space word.

A set of table instructions are provided to move byte or word-sized data to and from program space. See [Figure 3-4](#) and [Figure 3-5](#).

1. TBLRDL: Table Read Low
Word: Read the LS Word of the program address; P<15:0> maps to D<15:0>.
Byte: Read one of the LSB of the program address;
P<7:0> maps to the destination byte when byte select = 0;
P<15:8> maps to the destination byte when byte select = 1.
2. TBLWTL: Table Write Low (refer to [Section 5.0 “Flash Program Memory”](#) for details on Flash Programming)
3. TBLRDH: Table Read High
Word: Read the MS Word of the program address; P<23:16> maps to D<7:0>; D<15:8> will always be = 0.
Byte: Read one of the MSB of the program address;
P<23:16> maps to the destination byte when byte select = 0;
The destination byte will always be = 0 when byte select = 1.
4. TBLWTH: Table Write High (refer to [Section 5.0 “Flash Program Memory”](#) for details on Flash Programming)

FIGURE 3-3: PROGRAM DATA TABLE ACCESS (lsw)

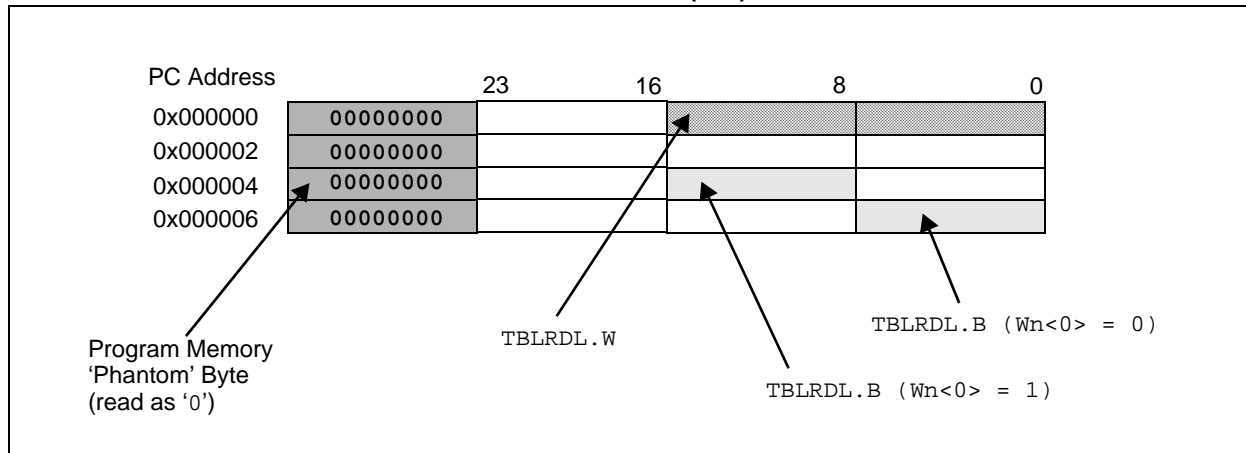
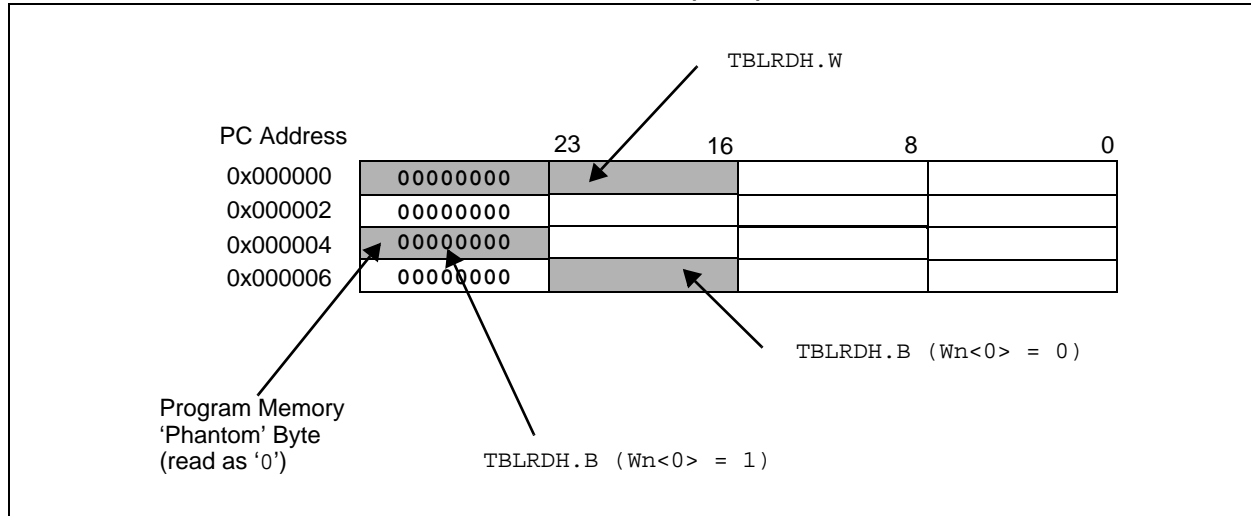


FIGURE 3-4: PROGRAM DATA TABLE ACCESS (MSB)



3.1.2 DATA ACCESS FROM PROGRAM MEMORY USING PROGRAM SPACE VISIBILITY

The upper 32 Kbytes of data space may optionally be mapped into any 16K word program space page. This provides transparent access of stored constant data from X data space without the need to use special instructions (i.e., TBLRDH/H, TBLWTL/H instructions).

Program space access through the data space occurs if the MSb of the data space EA is set and program space visibility is enabled by setting the PSV bit in the Core Control register (CORCON). The functions of CORCON are discussed in [Section 2.4 “DSP Engine”](#).

Data accesses to this area add an additional cycle to the instruction being executed, since two program memory fetches are required.

Note that the upper half of addressable data space is always part of the X data space. Therefore, when a DSP operation uses program space mapping to access this memory region, Y data space should typically contain state (variable) data for DSP operations, whereas X data space should typically contain coefficient (constant) data.

Although each data space address, 0x8000 and higher, maps directly into a corresponding program memory address (see [Figure 3-5](#)), only the lower 16 bits of the 24-bit program word are used to contain the data. The upper 8 bits should be programmed to force an illegal instruction to maintain machine robustness. Refer to the “16-bit MCU and DSC Programmer’s Reference Manual” (DS70157) for details on instruction encoding.

Note that by incrementing the PC by 2 for each program memory word, the LS 15 bits of data space addresses directly map to the LS 15 bits in the corresponding program space addresses. The remaining bits are provided by the Program Space Visibility Page register, PSVPAG<7:0>, as shown in [Figure 3-5](#).

Note: PSV access is temporarily disabled during table reads/writes.

For instructions that use PSV which are executed outside a REPEAT loop:

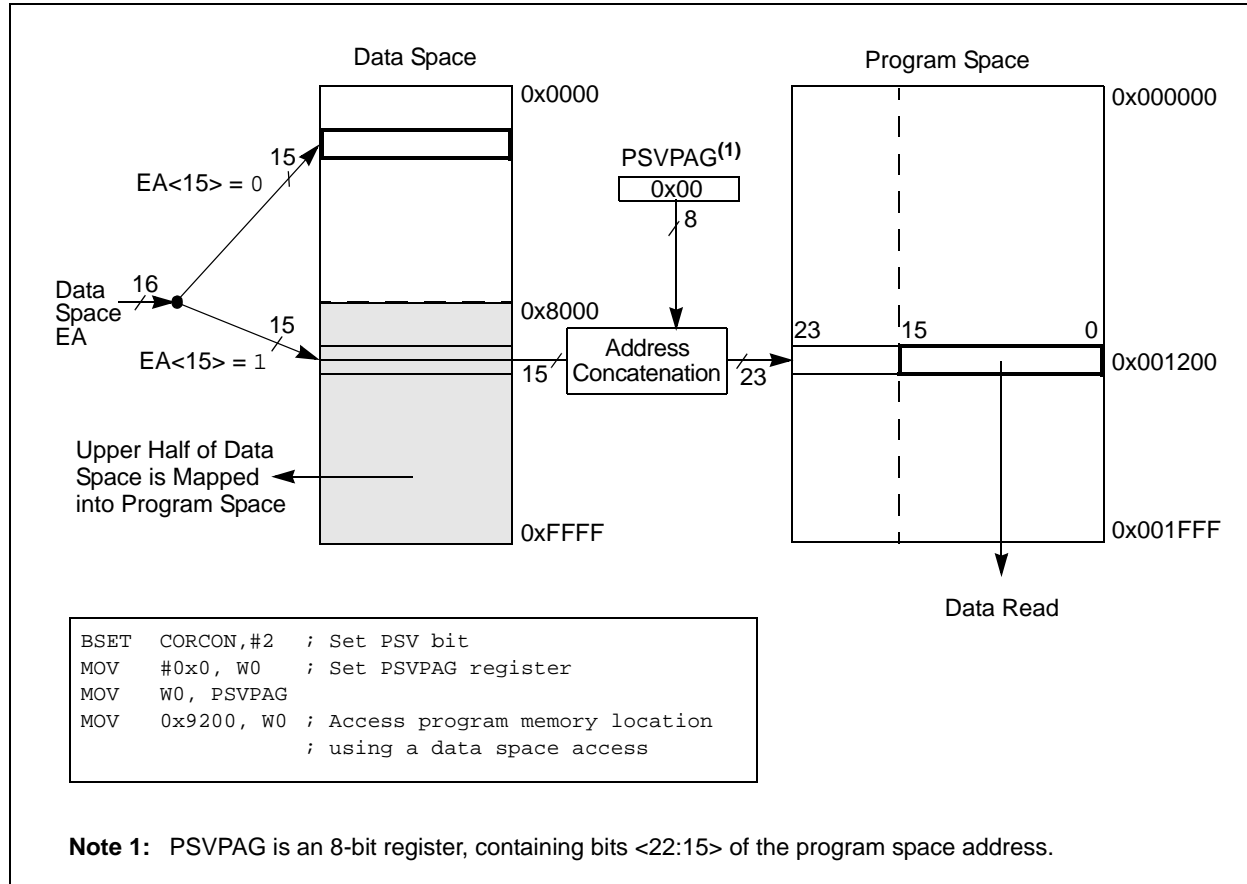
- The following instructions require one instruction cycle in addition to the specified execution time:
 - MAC class of instructions with data operand prefetch
 - MOV instructions
 - MOV.D instructions
- All other instructions require two instruction cycles in addition to the specified execution time of the instruction.

For instructions that use PSV which are executed inside a REPEAT loop:

- The following instances require two instruction cycles in addition to the specified execution time of the instruction:
 - Execution in the first iteration
 - Execution in the last iteration
 - Execution prior to exiting the loop due to an interrupt
 - Execution upon re-entering the loop after an interrupt is serviced
- Any other iteration of the REPEAT loop allow the instruction accessing data, using PSV, to execute in a single cycle.

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FIGURE 3-5: DATA SPACE WINDOW INTO PROGRAM SPACE OPERATION



3.2 Data Address Space

The core has two data spaces. The data spaces can be considered either separate (for some DSP instructions), or as one unified linear address range (for MCU instructions). The data spaces are accessed using two Address Generation Units (AGUs) and separate data paths.

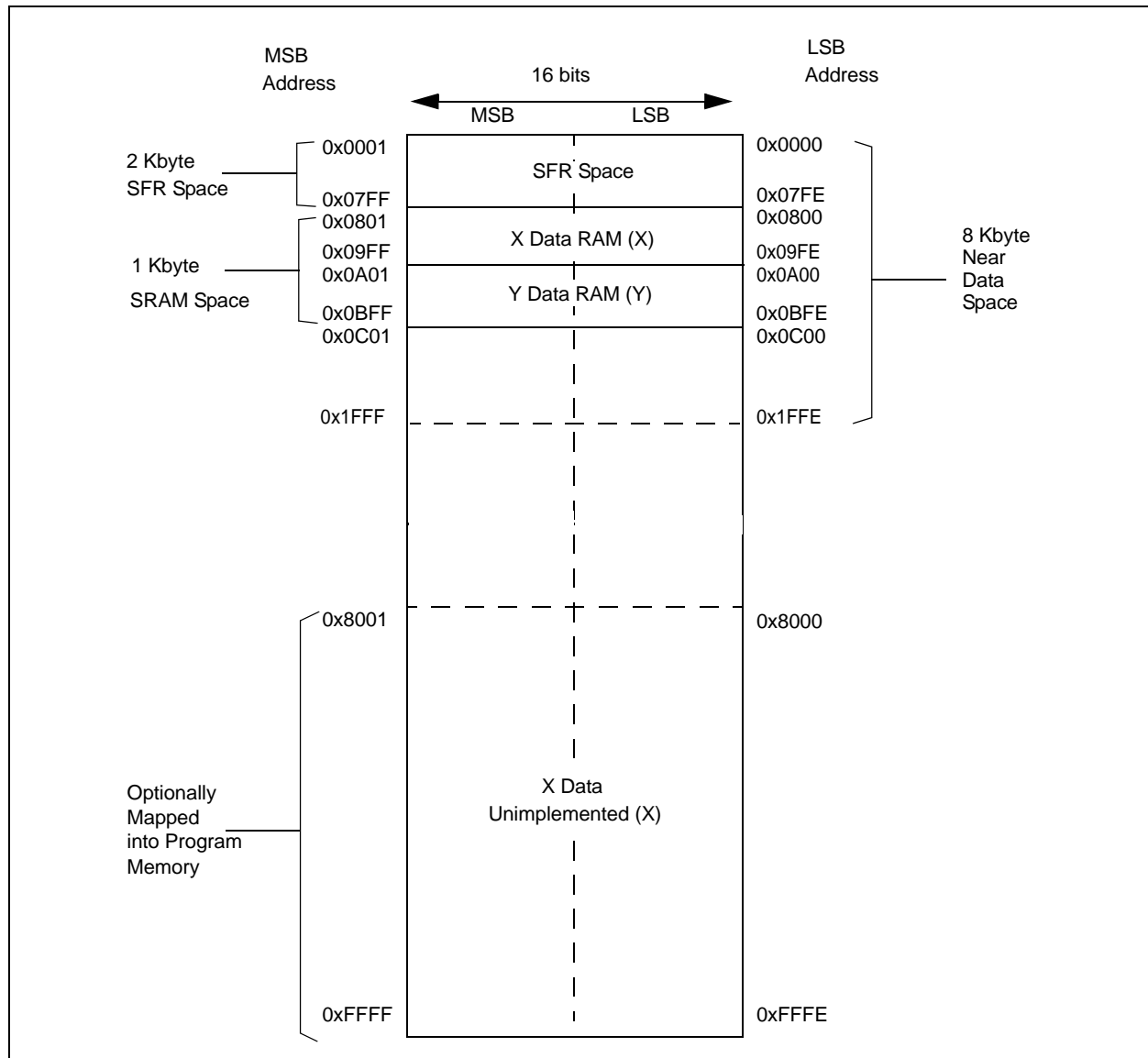
3.2.1 DATA SPACE MEMORY MAP

The data space memory is split into two blocks, X and Y data space. A key element of this architecture is that Y space is a subset of X space, and is fully contained within X space. In order to provide an apparent Linear Addressing space, X and Y spaces have contiguous addresses.

When executing any instruction other than one of the MAC class of instructions, the X block consists of the 64 Kbyte data address space (including all Y addresses). When executing one of the MAC class of instructions, the X block consists of the 64 Kbyte data address space, excluding the Y address block (for data reads only). In other words, all other instructions regard the entire data memory as one composite address space. The MAC class instructions extract the Y address space from data space and address it using EAs sourced from W10 and W11. The remaining X data space is addressed using W8 and W9. Both address spaces are concurrently accessed only with the MAC class instructions.

The data space memory map for the dsPIC30F2011 and dsPIC30F2012 is shown in [Figure 3-6](#). The data space memory map for the dsPIC30F3012 and dsPIC30F3013 is shown in [Figure 3-7](#).

FIGURE 3-6: dsPIC30F2011/2012 DATA SPACE MEMORY MAP



dsPIC30F2011/2012/3012/3013

FIGURE 3-7: dsPIC30F3012/3013 DATA SPACE MEMORY MAP

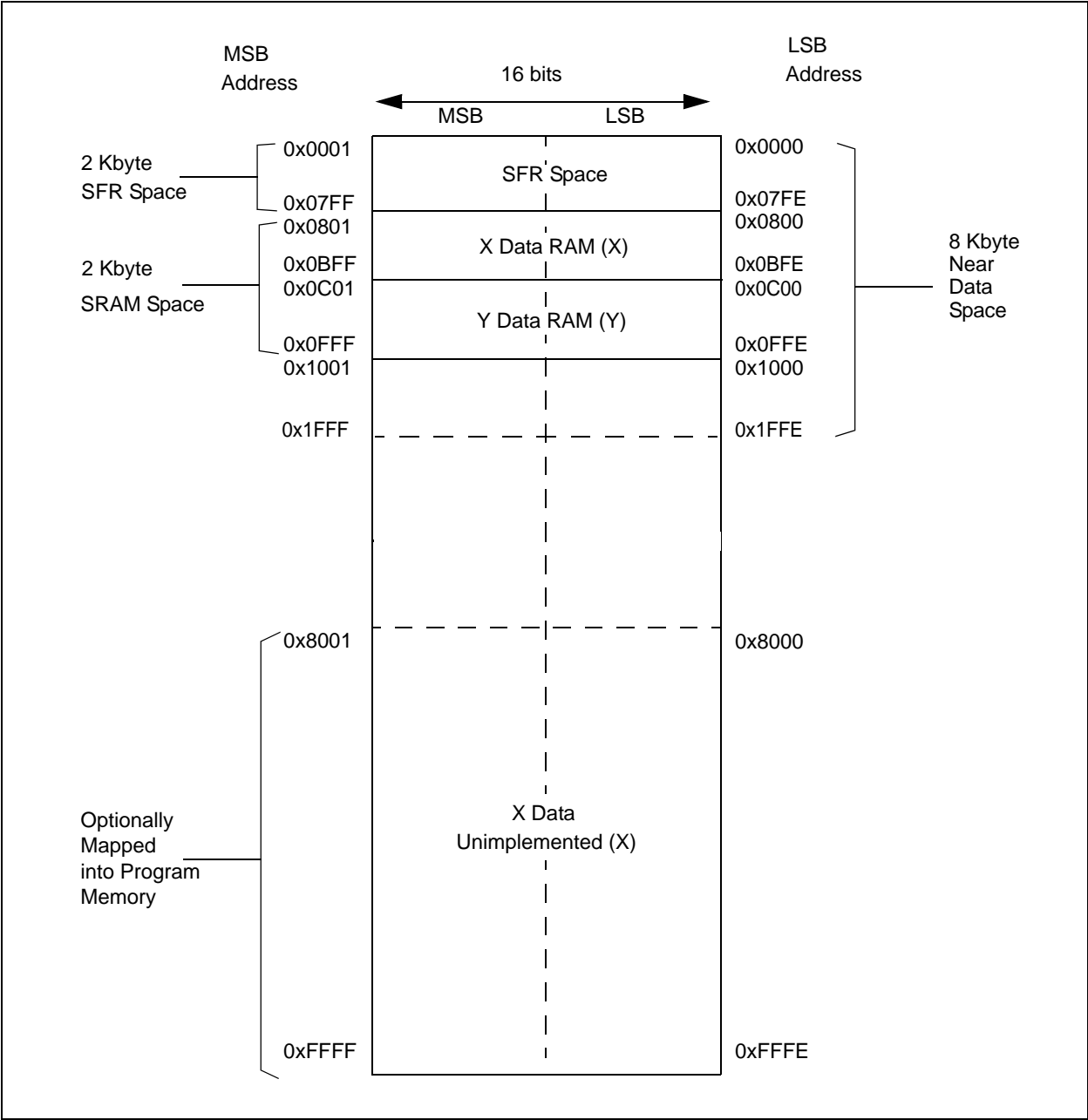
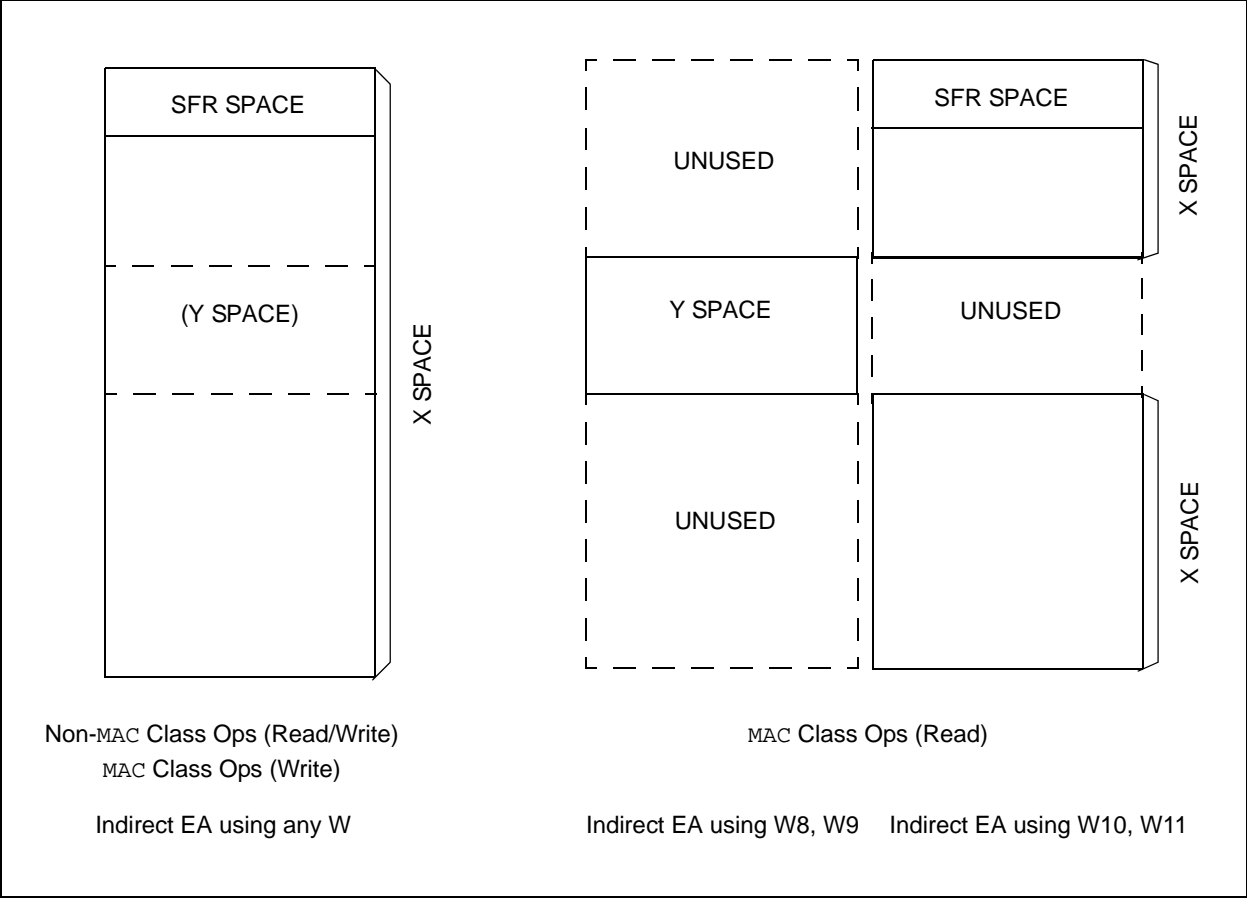


FIGURE 3-8: DATA SPACE FOR MCU AND DSP (MAC CLASS) INSTRUCTIONS EXAMPLE



3.2.2 DATA SPACES

The X data space is used by all instructions and supports all addressing modes. There are separate read and write data buses. The X read data bus is the return data path for all instructions that view data space as combined X and Y address space. It is also the X address space data path for the dual operand read instructions (MAC class). The X write data bus is the only write path to data space for all instructions.

The X data space also supports Modulo Addressing for all instructions, subject to Addressing mode restrictions. Bit-Reversed Addressing is only supported for writes to X data space.

The Y data space is used in concert with the X data space by the MAC class of instructions (CLR, ED, EDAC, MAC, MOVSA, MPY, MPY.N and MSC) to provide two concurrent data read paths. No writes occur across the Y bus. This class of instructions dedicates two W register pointers, W10 and W11, to always address Y data space, independent of X data space, whereas W8 and W9 always address X data space. Note that during accumulator write back, the data address space is considered a combination of X and Y data spaces, so the write occurs across the X bus. Consequently, the write can be to any address in the entire data space.

The Y data space can only be used for the data prefetch operation associated with the MAC class of instructions. It also supports Modulo Addressing for automated circular buffers. Of course, all other instructions can access the Y data address space through the X data path as part of the composite linear space.

The boundary between the X and Y data spaces is defined as shown in Figure 3-7 and is not user programmable. Should an EA point to data outside its own assigned address space, or to a location outside physical memory, an all zero word/byte is returned. For example, although Y address space is visible by all non-MAC instructions using any addressing mode, an attempt by a MAC instruction to fetch data from that space using W8 or W9 (X space pointers) returns 0x0000.

TABLE 3-2: EFFECT OF INVALID MEMORY ACCESSES

| Attempted Operation | Data Returned |
|---|---------------|
| EA = an unimplemented address | 0x0000 |
| W8 or W9 used to access Y data space in a MAC instruction | 0x0000 |
| W10 or W11 used to access X data space in a MAC instruction | 0x0000 |

All Effective Addresses are 16 bits wide and point to bytes within the data space. Therefore, the data space address range is 64 Kbytes or 32K words.

3.2.3 DATA SPACE WIDTH

The core data width is 16 bits. All internal registers are organized as 16-bit wide words. Data space memory is organized in byte addressable, 16-bit wide blocks.

3.2.4 DATA ALIGNMENT

To help maintain backward compatibility with PIC® MCU devices and improve data space memory usage efficiency, the dsPIC30F instruction set supports both word and byte operations. Data is aligned in data memory and registers as words, but all data space EAs resolve to bytes. Data byte reads read the complete word that contains the byte, using the LSB of any EA to determine which byte to select. The selected byte is placed onto the LSB of the X data path (no byte accesses are possible from the Y data path as the MAC class of instruction can only fetch words). That is, data memory and registers are organized as two parallel byte wide entities with shared (word) address decode but separate write lines. Data byte writes only write to the corresponding side of the array or register which matches the byte address.

As a consequence of this byte accessibility, all Effective Address calculations (including those generated by the DSP operations which are restricted to word-sized data) are internally scaled to step through word-aligned memory. For example, the core would recognize that Post-Modified Register Indirect Addressing mode [Ws++] results in a value of Ws + 1 for byte operations and Ws + 2 for word operations.

All word accesses must be aligned to an even address. Misaligned word data fetches are not supported, so care should be taken when mixing byte and word operations, or translating from 8-bit MCU code. Should a misaligned read or write be attempted, an address error trap is generated. If the error occurred on a read, the instruction underway is completed, whereas if it occurred on a write, the instruction is executed, but the write does not occur. In either case, a trap is then executed, allowing the system and/or user to examine the machine state prior to execution of the address fault.

FIGURE 3-9: DATA ALIGNMENT

| | 15 | MSB | 8 | 7 | LSB | 0 | |
|------|--------|-----|---|---|--------|---|------|
| 0001 | Byte 1 | | | | Byte 0 | | 0000 |
| 0003 | Byte 3 | | | | Byte 2 | | 0002 |
| 0005 | Byte 5 | | | | Byte 4 | | 0004 |

All byte loads into any W register are loaded into the LSB. The MSB is not modified.

A Sign-Extend (SE) instruction is provided to allow users to translate 8-bit signed data to 16-bit signed values. Alternatively, for 16-bit unsigned data, users can clear the MSB of any W register by executing a Zero-Extend (ZE) instruction on the appropriate address.

Although most instructions are capable of operating on word or byte data sizes, it should be noted that some instructions, including the DSP instructions, operate only on words.

3.2.5 NEAR DATA SPACE

An 8 Kbyte near data space is reserved in X address memory space between 0x0000 and 0x1FFF, which is directly addressable via a 13-bit absolute address field within all memory direct instructions. The remaining X address space and all of the Y address space is addressable indirectly. Additionally, the whole of X data space is addressable using MOV instructions, which support memory direct addressing with a 16-bit address field.

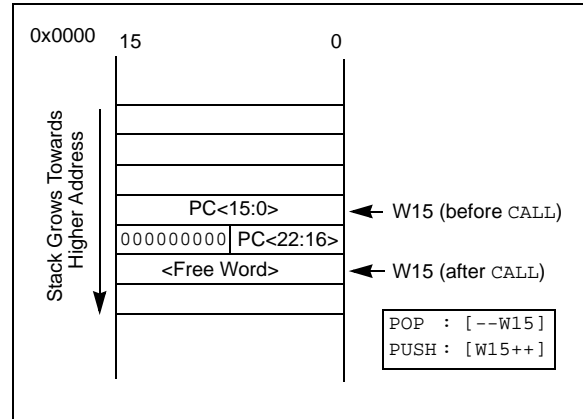
3.2.6 SOFTWARE STACK

The dsPIC DSC devices contain a software stack. W15 is used as the Stack Pointer.

The Stack Pointer always points to the first available free word and grows from lower addresses towards higher addresses. It pre-decrements for stack pops and post-increments for stack pushes, as shown in Figure 3-10. Note that for a PC push during any CALL instruction, the MSB of the PC is zero-extended before the push, ensuring that the MSB is always clear.

Note: A PC push during exception processing concatenates the SRL register to the MSB of the PC prior to the push.

FIGURE 3-10: CALL STACK FRAME



There is a Stack Pointer Limit register (SPLIM) associated with the Stack Pointer. SPLIM is uninitialized at Reset. As is the case for the Stack Pointer, SPLIM<0> is forced to '0' because all stack operations must be word aligned. Whenever an Effective Address (EA) is generated using W15 as a source or destination pointer, the address thus generated is compared with the value in SPLIM. If the contents of the Stack Pointer (W15) and the SPLIM register are equal, and a push operation is performed, a stack error trap does not occur. The stack error trap occurs on a subsequent push operation. Thus, for example, if it is desirable to cause a stack error trap when the stack grows beyond address 0x2000 in RAM, initialize the SPLIM with the value, 0x1FFE.

Similarly, a Stack Pointer underflow (stack error) trap is generated when the Stack Pointer address is found to be less than 0x0800, thus preventing the stack from interfering with the Special Function Register (SFR) space.

A write to the SPLIM register should not be immediately followed by an indirect read operation using W15.

TABLE 3-3: CORE REGISTER MAP

| SFR Name | Address (Home) | Bit 15 | Bit 14 | Bit 13 | Bit 12 | Bit 11 | Bit 10 | Bit 9 | Bit 8 | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Reset State | |
|----------|----------------|---------------------------|--------|--------|--------|--------|--------|-------|-------|--------|----------|-------|-------|-------|-------|-------|-------|---------------------|---------------------|
| W0 | 0000 | W0/WREG | | | | | | | | | | | | | | | | 0000 0000 0000 0000 | |
| W1 | 0002 | W1 | | | | | | | | | | | | | | | | 0000 0000 0000 0000 | |
| W2 | 0004 | W2 | | | | | | | | | | | | | | | | 0000 0000 0000 0000 | |
| W3 | 0006 | W3 | | | | | | | | | | | | | | | | 0000 0000 0000 0000 | |
| W4 | 0008 | W4 | | | | | | | | | | | | | | | | 0000 0000 0000 0000 | |
| W5 | 000A | W5 | | | | | | | | | | | | | | | | 0000 0000 0000 0000 | |
| W6 | 000C | W6 | | | | | | | | | | | | | | | | 0000 0000 0000 0000 | |
| W7 | 000E | W7 | | | | | | | | | | | | | | | | 0000 0000 0000 0000 | |
| W8 | 0010 | W8 | | | | | | | | | | | | | | | | 0000 0000 0000 0000 | |
| W9 | 0012 | W9 | | | | | | | | | | | | | | | | 0000 0000 0000 0000 | |
| W10 | 0014 | W10 | | | | | | | | | | | | | | | | 0000 0000 0000 0000 | |
| W11 | 0016 | W11 | | | | | | | | | | | | | | | | 0000 0000 0000 0000 | |
| W12 | 0018 | W12 | | | | | | | | | | | | | | | | 0000 0000 0000 0000 | |
| W13 | 001A | W13 | | | | | | | | | | | | | | | | 0000 0000 0000 0000 | |
| W14 | 001C | W14 | | | | | | | | | | | | | | | | 0000 0000 0000 0000 | |
| W15 | 001E | W15 | | | | | | | | | | | | | | | | 0000 1000 0000 0000 | |
| SPLIM | 0020 | SPLIM | | | | | | | | | | | | | | | | 0000 0000 0000 0000 | |
| ACCAL | 0022 | ACCAL | | | | | | | | | | | | | | | | 0000 0000 0000 0000 | |
| ACCAH | 0024 | ACCAH | | | | | | | | | | | | | | | | 0000 0000 0000 0000 | |
| ACCAU | 0026 | Sign Extension (ACCA<39>) | | | | | | | | | ACCAU | | | | | | | 0000 0000 0000 0000 | |
| ACCBH | 0028 | ACCBH | | | | | | | | | | | | | | | | 0000 0000 0000 0000 | |
| ACCBH | 002A | ACCBH | | | | | | | | | | | | | | | | 0000 0000 0000 0000 | |
| ACCBU | 002C | Sign Extension (ACCB<39>) | | | | | | | | | ACCBU | | | | | | | 0000 0000 0000 0000 | |
| PCL | 002E | PCL | | | | | | | | | | | | | | | | 0000 0000 0000 0000 | |
| PCH | 0030 | — | — | — | — | — | — | — | — | — | PCH | | | | | | | 0000 0000 0000 0000 | |
| TBLPAG | 0032 | — | — | — | — | — | — | — | — | TBLPAG | | | | | | | | 0000 0000 0000 0000 | |
| PSVPAG | 0034 | — | — | — | — | — | — | — | — | PSVPAG | | | | | | | | 0000 0000 0000 0000 | |
| RCOUNT | 0036 | RCOUNT | | | | | | | | | | | | | | | | uuuu uuuu uuuu uuuu | |
| DCOUNT | 0038 | DCOUNT | | | | | | | | | | | | | | | | uuuu uuuu uuuu uuuu | |
| DOSTARTL | 003A | DOSTARTL | | | | | | | | | | | | | | | | 0 | uuuu uuuu uuuu uuu0 |
| DOSTARTH | 003C | — | — | — | — | — | — | — | — | — | DOSTARTH | | | | | | | 0000 0000 0uuu uuuu | |
| DOENDL | 003E | DOENDL | | | | | | | | | | | | | | | | 0 | uuuu uuuu uuuu uuu0 |
| DOENDH | 0040 | — | — | — | — | — | — | — | — | — | DOENDH | | | | | | | 0000 0000 0uuu uuuu | |
| SR | 0042 | OA | OB | SA | SB | OAB | SAB | DA | DC | IPL2 | IPL1 | IPL0 | RA | N | OV | Z | C | 0000 0000 0000 0000 | |

Legend: u = uninitialized bit; — = unimplemented bit, read as '0'

Note: Refer to the “dsPIC30F Family Reference Manual” (DS70046) for descriptions of register bit fields.

TABLE 3-3: CORE REGISTER MAP (CONTINUED)

| SFR Name | Address (Home) | Bit 15 | Bit 14 | Bit 13 | Bit 12 | Bit 11 | Bit 10 | Bit 9 | Bit 8 | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Reset State |
|----------|----------------|----------|----------|---------------|--------|----------|--------|-------|-------|----------|-------|-------|--------|----------|-------|-------|-------|---------------------|
| CORCON | 0044 | — | — | — | US | EDT | DL2 | DL1 | DL0 | SATA | SATB | SATDW | ACCSAT | IPL3 | PSV | RND | IF | 0000 0000 0010 0000 |
| MODCON | 0046 | XMODEN | YMODEN | — | — | BWM<3:0> | | | | YWM<3:0> | | | | XWM<3:0> | | | | 0000 0000 0000 0000 |
| XMODSRT | 0048 | XS<15:1> | | | | | | | | | | | | | | | 0 | uuuu uuuu uuuu uuu0 |
| XMODEND | 004A | XE<15:1> | | | | | | | | | | | | | | | 1 | uuuu uuuu uuuu uuu1 |
| YMODSRT | 004C | YS<15:1> | | | | | | | | | | | | | | | 0 | uuuu uuuu uuuu uuu0 |
| YMODEND | 004E | YE<15:1> | | | | | | | | | | | | | | | 1 | uuuu uuuu uuuu uuu1 |
| XBREV | 0050 | BREN | XB<14:0> | | | | | | | | | | | | | | | uuuu uuuu uuuu uuuu |
| DISICNT | 0052 | — | — | DISICNT<13:0> | | | | | | | | | | | | | | 0000 0000 0000 0000 |

Legend: u = uninitialized bit; — = unimplemented bit, read as '0'

Note: Refer to the “dsPIC30F Family Reference Manual” (DS70046) for descriptions of register bit fields.

NOTES:

4.0 ADDRESS GENERATOR UNITS

Note: This data sheet summarizes features of this group of dsPIC30F devices and is not intended to be a complete reference source. For more information on the CPU, peripherals, register descriptions and general device functionality, refer to the “dsPIC30F Family Reference Manual” (DS70046). For more information on the device instruction set and programming, refer to the “16-bit MCU and DSC Programmer’s Reference Manual” (DS70157).

The dsPIC DSC core contains two independent address generator units: the X AGU and Y AGU. The Y AGU supports word-sized data reads for the DSP MAC class of instructions only. The dsPIC DSC AGUs support three types of data addressing:

- Linear Addressing
- Modulo (Circular) Addressing
- Bit-Reversed Addressing

Linear and Modulo Data Addressing modes can be applied to data space or program space. Bit-Reversed Addressing is only applicable to data space addresses.

4.1 Instruction Addressing Modes

The addressing modes in Table 4-1 form the basis of the addressing modes optimized to support the specific features of individual instructions. The addressing modes provided in the MAC class of instructions are somewhat different from those in the other instruction types.

4.1.1 FILE REGISTER INSTRUCTIONS

Most file register instructions use a 13-bit address field (f) to directly address data present in the first 8192 bytes of data memory (near data space). Most file register instructions employ a working register, W0, which is denoted as WREG in these instructions. The destination is typically either the same file register or WREG (with the exception of the MUL instruction), which writes the result to a register or register pair. The MOV instruction allows additional flexibility and can access the entire data space during file register operation.

4.1.2 MCU INSTRUCTIONS

The three-operand MCU instructions are of the form:

Operand 3 = Operand 1 <function> Operand 2

where Operand 1 is always a working register (i.e., the addressing mode can only be register direct), which is referred to as Wb. Operand 2 can be a W register, fetched from data memory or a 5-bit literal. The result location can be either a W register or an address location. The following addressing modes are supported by MCU instructions:

- Register Direct
- Register Indirect
- Register Indirect Post-modified
- Register Indirect Pre-modified
- 5-bit or 10-bit Literal

Note: Not all instructions support all the addressing modes given above. Individual instructions may support different subsets of these addressing modes.

TABLE 4-1: FUNDAMENTAL ADDRESSING MODES SUPPORTED

| Addressing Mode | Description |
|--|--|
| File Register Direct | The address of the File register is specified explicitly. |
| Register Direct | The contents of a register are accessed directly. |
| Register Indirect | The contents of Wn forms the EA. |
| Register Indirect Post-modified | The contents of Wn forms the EA. Wn is post-modified (incremented or decremented) by a constant value. |
| Register Indirect Pre-modified | Wn is pre-modified (incremented or decremented) by a signed constant value to form the EA. |
| Register Indirect with Register Offset | The sum of Wn and Wb forms the EA. |
| Register Indirect with Literal Offset | The sum of Wn and a literal forms the EA. |

4.1.3 MOVE AND ACCUMULATOR INSTRUCTIONS

Move instructions and the DSP accumulator class of instructions provide a greater degree of addressing flexibility than other instructions. In addition to the addressing modes supported by most MCU instructions, move and accumulator instructions also support Register Indirect with Register Offset Addressing mode, also referred to as Register Indexed mode.

Note: For the `MOV` instructions, the addressing mode specified in the instruction can differ for the source and destination EA. However, the 4-bit `Wb` (register offset) field is shared between both source and destination (but typically only used by one).

In summary, the following addressing modes are supported by move and accumulator instructions:

- Register Direct
- Register Indirect
- Register Indirect Post-modified
- Register Indirect Pre-modified
- Register Indirect with Register Offset (Indexed)
- Register Indirect with Literal Offset
- 8-bit Literal
- 16-bit Literal

Note: Not all instructions support all the addressing modes given above. Individual instructions may support different subsets of these addressing modes.

4.1.4 MAC INSTRUCTIONS

The dual source operand DSP instructions (`CLR`, `ED`, `EDAC`, `MAC`, `MPY`, `MPY.N`, `MOVSAC` and `MSC`), also referred to as `MAC` instructions, utilize a simplified set of addressing modes to allow the user to effectively manipulate the data pointers through register indirect tables.

The two source operand prefetch registers must belong to the set {`W8`, `W9`, `W10`, `W11`}. For data reads, `W8` and `W9` are always directed to the X RAGU. `W10` and `W11` are always directed to the Y AGU. The effective addresses generated (before and after modification) must, therefore, be valid addresses within X data space for `W8` and `W9` and Y data space for `W10` and `W11`.

Note: Register Indirect with Register Offset addressing is only available for `W9` (in X space) and `W11` (in Y space).

In summary, the following addressing modes are supported by the `MAC` class of instructions:

- Register Indirect
- Register Indirect Post-modified by 2
- Register Indirect Post-modified by 4
- Register Indirect Post-modified by 6
- Register Indirect with Register Offset (Indexed)

4.1.5 OTHER INSTRUCTIONS

Besides the various addressing modes outlined above, some instructions use literal constants of various sizes. For example, `BRA` (branch) instructions use 16-bit signed literals to specify the branch destination directly, whereas the `DISI` instruction uses a 14-bit unsigned literal field. In some instructions, such as `ADD ACC`, the source of an operand or result is implied by the opcode itself. Certain operations, such as `NOB`, do not have any operands.

4.2 Modulo Addressing

Modulo Addressing is a method of providing an automated means to support circular data buffers using hardware. The objective is to remove the need for software to perform data address boundary checks when executing tightly looped code, as is typical in many DSP algorithms.

Modulo Addressing can operate in either data or program space (since the data pointer mechanism is essentially the same for both). One circular buffer can be supported in each of the X (which also provides the pointers into program space) and Y data spaces. Modulo Addressing can operate on any `W` register pointer. However, it is not advisable to use `W14` or `W15` for Modulo Addressing since these two registers are used as the Stack Frame Pointer and Stack Pointer, respectively.

In general, any particular circular buffer can only be configured to operate in one direction, as there are certain restrictions on the buffer Start address (for incrementing buffers), or end address (for decrementing buffers) based upon the direction of the buffer.

The only exception to the usage restrictions is for buffers that have a power-of-2 length. As these buffers satisfy the Start and the end address criteria, they can operate in a Bidirectional mode (i.e., address boundary checks are performed on both the lower and upper address boundaries).

4.2.1 START AND END ADDRESS

The Modulo Addressing scheme requires that a starting and an ending address be specified and loaded into the 16-bit Modulo Buffer Address registers: XMODSRT, XMODEND, YMODSRT and YMODEND (see Table 3-3).

Note: Y space Modulo Addressing EA calculations assume word-sized data (LSb of every EA is always clear).

The length of a circular buffer is not directly specified. It is determined by the difference between the corresponding Start and end addresses. The maximum possible length of the circular buffer is 32K words (64 Kbytes).

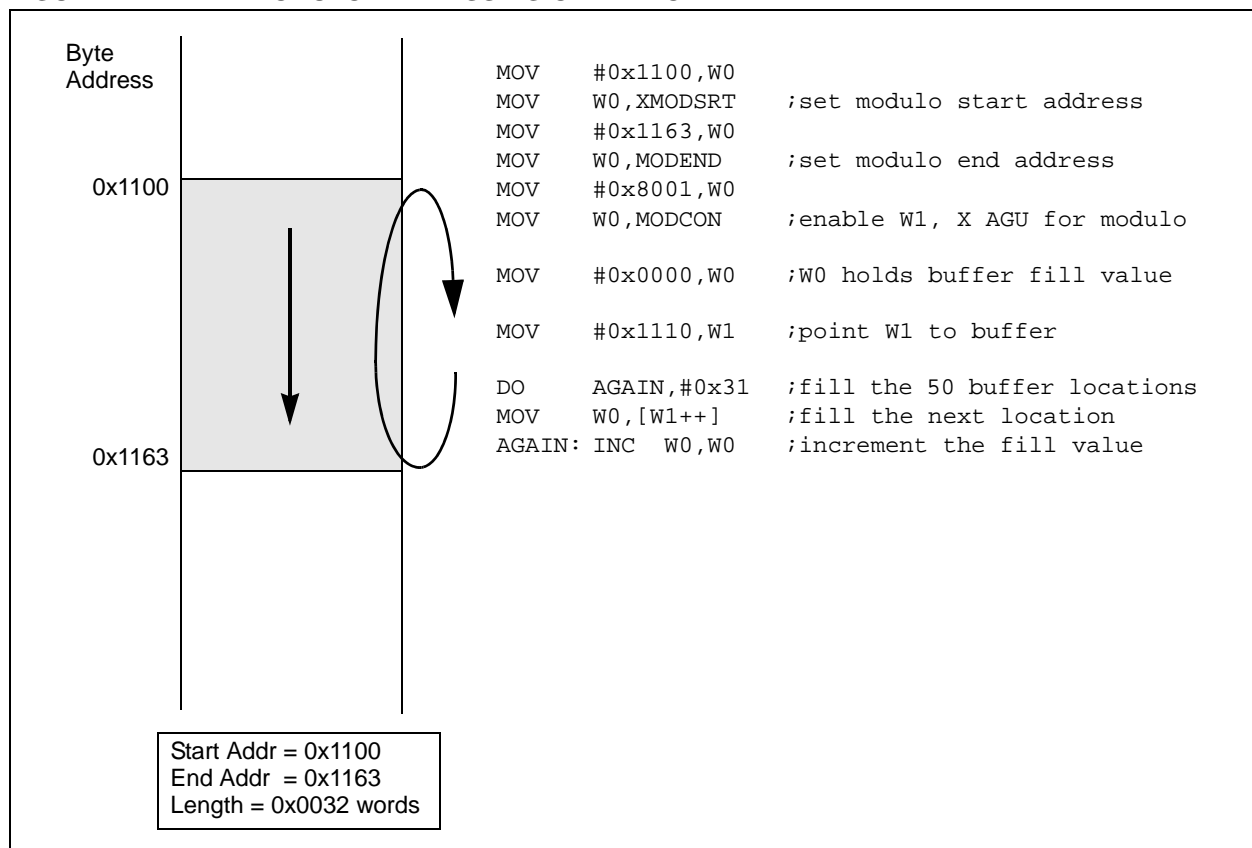
4.2.2 W ADDRESS REGISTER SELECTION

The Modulo and Bit-Reversed Addressing Control register, MODCON<15:0>, contains enable flags as well as a W register field to specify the W address registers. The XWM and YWM fields select which registers operate with Modulo Addressing. If XWM = 15, X RAGU and X WAGU Modulo Addressing is disabled. Similarly, if YWM = 15, Y AGU Modulo Addressing is disabled.

The X Address Space Pointer W register (XWM), to which Modulo Addressing is to be applied, is stored in MODCON<3:0> (see Table 3-3). Modulo Addressing is enabled for X data space when XWM is set to any value other than '15' and the XMODEN bit is set at MODCON<15>.

The Y Address Space Pointer W register (YWM), to which Modulo Addressing is to be applied, is stored in MODCON<7:4>. Modulo Addressing is enabled for Y data space when YWM is set to any value other than '15' and the YMODEN bit is set at MODCON<14>.

FIGURE 4-1: MODULO ADDRESSING OPERATION EXAMPLE



4.2.3 MODULO ADDRESSING APPLICABILITY

Modulo Addressing can be applied to the Effective Address (EA) calculation associated with any W register. It is important to realize that the address boundaries check for addresses less than, or greater than the upper (for incrementing buffers), and lower (for decrementing buffers) boundary addresses (not just equal to). Address changes may, therefore, jump beyond boundaries and still be adjusted correctly.

Note: The modulo corrected Effective Address is written back to the register only when Pre-Modify or Post-Modify Addressing mode is used to compute the EA. When an address offset (e.g., [W7+W2]) is used, Modulo address correction is performed, but the contents of the register remain unchanged.

4.3 Bit-Reversed Addressing

Bit-Reversed Addressing is intended to simplify data re-ordering for radix-2 FFT algorithms. It is supported by the X AGU for data writes only.

The modifier, which may be a constant value or register contents, is regarded as having its bit order reversed. The address source and destination are kept in normal order. Thus, the only operand requiring reversal is the modifier.

4.3.1 BIT-REVERSED ADDRESSING IMPLEMENTATION

Bit-Reversed Addressing is enabled when:

- BWM (W register selection) in the MODCON register is any value other than '15' (the stack cannot be accessed using Bit-Reversed Addressing) and
- The BREN bit is set in the XBREV register and
- The addressing mode used is Register Indirect with Pre-Increment or Post-Increment.

If the length of a bit-reversed buffer is $M = 2^N$ bytes, then the last 'N' bits of the data buffer Start address must be zeros.

XB<14:0> is the bit-reversed address modifier or 'pivot point' which is typically a constant. In the case of an FFT computation, its value is equal to half of the FFT data buffer size.

Note: All bit-reversed EA calculations assume word-sized data (LSb of every EA is always clear). The XB value is scaled accordingly to generate compatible (byte) addresses.

When enabled, Bit-Reversed Addressing is only executed for register indirect with pre-increment or post-increment addressing and word-sized data writes. It does not function for any other addressing mode or for byte-sized data. Normal addresses are generated instead. When Bit-Reversed Addressing is active, the W address pointer is always added to the address modifier (XB) and the offset associated with the Register Indirect Addressing mode is ignored. In addition, as word-sized data is a requirement, the LSb of the EA is ignored (and always clear).

Note: Modulo Addressing and Bit-Reversed Addressing should not be enabled together. In the event that the user attempts to do this, Bit-Reversed Addressing assumes priority when active for the X WAGU, and X WAGU Modulo Addressing is disabled. However, Modulo Addressing continues to function in the X RAGU.

If Bit-Reversed Addressing has already been enabled by setting the BREN bit (XBREV<15>), then a write to the XBREV register should not be immediately followed by an indirect read operation using the W register that has been designated as the bit-reversed pointer.

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FIGURE 4-2: BIT-REVERSED ADDRESS EXAMPLE

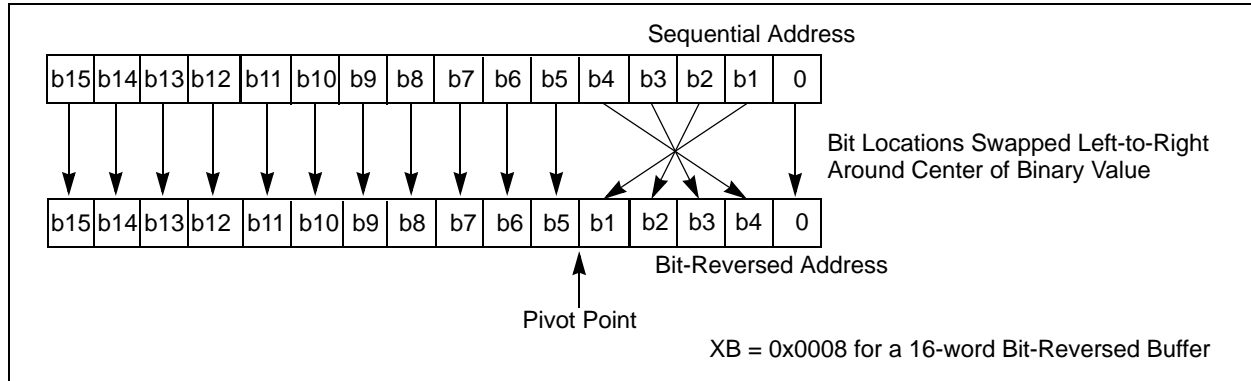


TABLE 4-2: BIT-REVERSED ADDRESS SEQUENCE (16-ENTRY)

| Normal Address | | | | | Bit-Reversed Address | | | | |
|----------------|----|----|----|---------|----------------------|----|----|----|---------|
| A3 | A2 | A1 | A0 | Decimal | A3 | A2 | A1 | A0 | Decimal |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 8 |
| 0 | 0 | 1 | 0 | 2 | 0 | 1 | 0 | 0 | 4 |
| 0 | 0 | 1 | 1 | 3 | 1 | 1 | 0 | 0 | 12 |
| 0 | 1 | 0 | 0 | 4 | 0 | 0 | 1 | 0 | 2 |
| 0 | 1 | 0 | 1 | 5 | 1 | 0 | 1 | 0 | 10 |
| 0 | 1 | 1 | 0 | 6 | 0 | 1 | 1 | 0 | 6 |
| 0 | 1 | 1 | 1 | 7 | 1 | 1 | 1 | 0 | 14 |
| 1 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 1 | 1 |
| 1 | 0 | 0 | 1 | 9 | 1 | 0 | 0 | 1 | 9 |
| 1 | 0 | 1 | 0 | 10 | 0 | 1 | 0 | 1 | 5 |
| 1 | 0 | 1 | 1 | 11 | 1 | 1 | 0 | 1 | 13 |
| 1 | 1 | 0 | 0 | 12 | 0 | 0 | 1 | 1 | 3 |
| 1 | 1 | 0 | 1 | 13 | 1 | 0 | 1 | 1 | 11 |
| 1 | 1 | 1 | 0 | 14 | 0 | 1 | 1 | 1 | 7 |
| 1 | 1 | 1 | 1 | 15 | 1 | 1 | 1 | 1 | 15 |

TABLE 4-3: BIT-REVERSED ADDRESS MODIFIER VALUES FOR XBREV REGISTER

| Buffer Size (Words) | XB<14:0> Bit-Reversed Address Modifier Value |
|---------------------|--|
| 1024 | 0x0200 |
| 512 | 0x0100 |
| 256 | 0x0080 |
| 128 | 0x0040 |
| 64 | 0x0020 |
| 32 | 0x0010 |
| 16 | 0x0008 |
| 8 | 0x0004 |
| 4 | 0x0002 |
| 2 | 0x0001 |

NOTES:

5.0 FLASH PROGRAM MEMORY

Note: This data sheet summarizes features of this group of dsPIC30F devices and is not intended to be a complete reference source. For more information on the CPU, peripherals, register descriptions and general device functionality, refer to the “dsPIC30F Family Reference Manual” (DS70046). For more information on the device instruction set and programming, refer to the “16-bit MCU and DSC Programmer’s Reference Manual” (DS70157).

The dsPIC30F family of devices contains internal program Flash memory for executing user code. There are two methods by which the user can program this memory:

1. Run-Time Self-Programming (RTSP)
2. In-Circuit Serial Programming™ (ICSP™)

5.1 In-Circuit Serial Programming (ICSP)

dsPIC30F devices can be serially programmed while in the end application circuit. This is simply done with two lines for Programming Clock and Programming Data (which are named PGC and PGD respectively), and three other lines for Power (VDD), Ground (VSS) and Master Clear (MCLR). This allows customers to manufacture boards with unprogrammed devices, and then program the microcontroller just before shipping the product. This also allows the most recent firmware or a custom firmware to be programmed.

5.2 Run-Time Self-Programming (RTSP)

RTSP is accomplished using TBLRD (table read) and TBLWT (table write) instructions.

With RTSP, the user may erase program memory, 32 instructions (96 bytes) at a time and can write program memory data, 32 instructions (96 bytes) at a time.

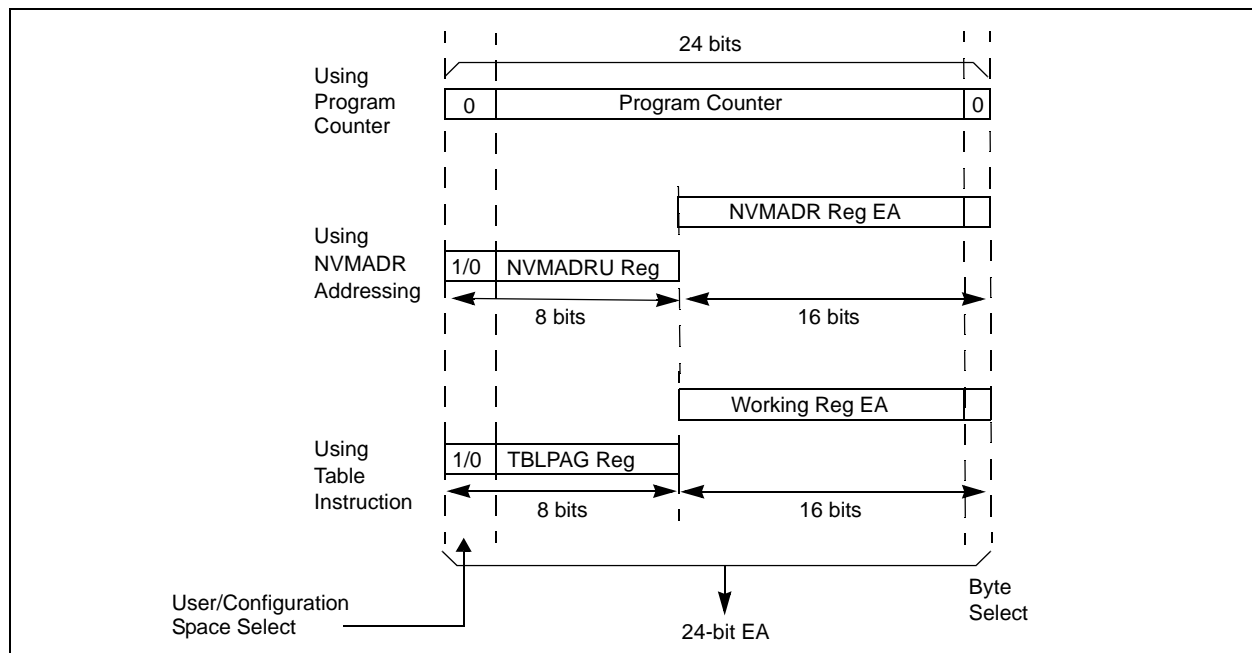
5.3 Table Instruction Operation Summary

The TBLRDL and the TBLWTL instructions are used to read or write to bits<15:0> of program memory. TBLRDL and TBLWTL can access program memory in Word or Byte mode.

The TBLRDH and TBLWTH instructions are used to read or write to bits<23:16> of program memory. TBLRDH and TBLWTH can access program memory in Word or Byte mode.

A 24-bit program memory address is formed using bits<7:0> of the TBLPAG register and the Effective Address (EA) from a W register specified in the table instruction, as shown in Figure 5-1.

FIGURE 5-1: ADDRESSING FOR TABLE AND NVM REGISTERS



5.4 RTSP Operation

The dsPIC30F Flash program memory is organized into rows and panels. Each row consists of 32 instructions or 96 bytes. Each panel consists of 128 rows or 4K x 24 instructions. RTSP allows the user to erase one row (32 instructions) at a time and to program four instructions at one time. RTSP may be used to program multiple program memory panels, but the table pointer must be changed at each panel boundary.

Each panel of program memory contains write latches that hold 32 instructions of programming data. Prior to the actual programming operation, the write data must be loaded into the panel write latches. The data to be programmed into the panel is loaded in sequential order into the write latches; instruction 0, instruction 1, etc. The instruction words loaded must always be from a 32 address boundary.

The basic sequence for RTSP programming is to set up a Table Pointer, then do a series of TBLWT instructions to load the write latches. Programming is performed by setting the special bits in the NVMCON register. 32 TBLWTL and four TBLWTH instructions are required to load the 32 instructions. If multiple panel programming is required, the Table Pointer needs to be changed and the next set of multiple write latches written.

All of the table write operations are single-word writes (2 instruction cycles), because only the table latches are written. A programming cycle is required for programming each row.

The Flash Program Memory is readable, writable and erasable during normal operation over the entire VDD range.

5.5 Control Registers

The four SFRs used to read and write the program Flash memory are:

- NVMCON
- NVMADR
- NVMADRU
- NVMKEY

5.5.1 NVMCON REGISTER

The NVMCON register controls which blocks are to be erased, which memory type is to be programmed, and start of the programming cycle.

5.5.2 NVMADR REGISTER

The NVMADR register is used to hold the lower two bytes of the Effective Address. The NVMADR register captures the EA<15:0> of the last table instruction that has been executed and selects the row to write.

5.5.3 NVMADRU REGISTER

The NVMADRU register is used to hold the upper byte of the Effective Address. The NVMADRU register captures the EA<23:16> of the last table instruction that has been executed.

5.5.4 NVMKEY REGISTER

NVMKEY is a write-only register that is used for write protection. To start a programming or an erase sequence, the user must consecutively write 0x55 and 0xAA to the NVMKEY register. Refer to [Section 5.6 “Programming Operations”](#) for further details.

| |
|---|
| Note: The user can also directly write to the NVMADR and NVMADRU registers to specify a program memory address for erasing or programming. |
|---|

5.6 Programming Operations

A complete programming sequence is necessary for programming or erasing the internal Flash in RTSP mode. A programming operation is nominally 2 msec in duration and the processor stalls (waits) until the operation is finished. Setting the WR bit (NVMCON<15>) starts the operation and the WR bit is automatically cleared when the operation is finished.

5.6.1 PROGRAMMING ALGORITHM FOR PROGRAM FLASH

The user can erase or program one row of program Flash memory at a time. The general process is:

1. Read one row of program Flash (32 instruction words) and store into data RAM as a data "image".
2. Update the data image with the desired new data.
3. Erase program Flash row.
 - a) Set up NVMCON register for multi-word, program Flash, erase, and set WREN bit.
 - b) Write address of row to be erased into NVMADRU/NVMADR.
 - c) Write 0x55 to NVMKEY.
 - d) Write 0xAA to NVMKEY.
 - e) Set the WR bit. This begins erase cycle.
 - f) CPU stalls for the duration of the erase cycle.
 - g) The WR bit is cleared when erase cycle ends.

4. Write 32 instruction words of data from data RAM "image" into the program Flash write latches.
5. Program 32 instruction words into program Flash.
 - a) Set up NVMCON register for multi-word, program Flash, program, and set WREN bit.
 - b) Write 0x55 to NVMKEY.
 - c) Write 0xAA to NVMKEY.
 - d) Set the WR bit. This begins program cycle.
 - e) CPU stalls for duration of the program cycle.
 - f) The WR bit is cleared by the hardware when program cycle ends.
6. Repeat steps 1 through 5 as needed to program desired amount of program Flash memory.

5.6.2 ERASING A ROW OF PROGRAM MEMORY

Example 5-1 shows a code sequence that can be used to erase a row (32 instructions) of program memory.

EXAMPLE 5-1: ERASING A ROW OF PROGRAM MEMORY

```
; Setup NVMCON for erase operation, multi word write
; program memory selected, and writes enabled
    MOV    #0x4041,W0
    MOV    W0,NVMCON
; Init pointer to row to be ERASED
    MOV    #tblpage(PROG_ADDR),W0
    MOV    W0,NVMADRU
    MOV    #tbloffset(PROG_ADDR),W0
    MOV    W0,NVMADR
    DISI   #5
; Block all interrupts with priority <7 for
; next 5 instructions

    MOV    #0x55,W0
    MOV    W0,NVMKEY
    MOV    #0xAA,W1
    MOV    W1,NVMKEY
    BSET   NVMCON,#WR
    NOP
    NOP
; Write the 0x55 key
;
; Write the 0xAA key
; Start the erase sequence
; Insert two NOPs after the erase
; command is asserted
```

5.6.3 LOADING WRITE LATCHES

[Example 5-2](#) shows a sequence of instructions that can be used to load the 96 bytes of write latches. 32 TBLWTL and 32 TBLWTH instructions are needed to load the write latches selected by the Table Pointer.

5.6.4 INITIATING THE PROGRAMMING SEQUENCE

For protection, the write initiate sequence for NVMKEY must be used to allow any erase or program operation to proceed. After the programming command has been executed, the user must wait for the programming time until programming is complete. The two instructions following the start of the programming sequence should be NOPs as shown in [Example 5-3](#).

EXAMPLE 5-2: LOADING WRITE LATCHES

```
; Set up a pointer to the first program memory location to be written
; program memory selected, and writes enabled
MOV    #0x0000,W0                                ;
MOV    W0,TBLPAG                                ; Initialize PM Page Boundary SFR
MOV    #0x6000,W0                                ; An example program memory address
; Perform the TBLWT instructions to write the latches
; 0th_program_word
MOV    #LOW_WORD_0,W2                            ;
MOV    #HIGH_BYTE_0,W3                          ;
TBLWTL W2,[W0]                                   ; Write PM low word into program latch
TBLWTH W3,[W0++]                                 ; Write PM high byte into program latch
; 1st_program_word
MOV    #LOW_WORD_1,W2                            ;
MOV    #HIGH_BYTE_1,W3                          ;
TBLWTL W2,[W0]                                   ; Write PM low word into program latch
TBLWTH W3,[W0++]                                 ; Write PM high byte into program latch
; 2nd_program_word
MOV    #LOW_WORD_2,W2                            ;
MOV    #HIGH_BYTE_2,W3                          ;
TBLWTL W2,[W0]                                   ; Write PM low word into program latch
TBLWTH W3,[W0++]                                 ; Write PM high byte into program latch
.
.
.
; 31st_program_word
MOV    #LOW_WORD_31,W2                           ;
MOV    #HIGH_BYTE_31,W3                         ;
TBLWTL W2,[W0]                                   ; Write PM low word into program latch
TBLWTH W3,[W0++]                                 ; Write PM high byte into program latch
```

Note: In [Example 5-2](#), the contents of the upper byte of W3 has no effect.

EXAMPLE 5-3: INITIATING A PROGRAMMING SEQUENCE

```
DISI    #5                                ; Block all interrupts with priority <7 for
                                           ; next 5 instructions
MOV     #0x55,W0                          ;
MOV     W0,NVMKEY                         ; Write the 0x55 key
MOV     #0xAA,W1                          ;
MOV     W1,NVMKEY                         ; Write the 0xAA key
BSET    NVMCON,#WR                        ; Start the erase sequence
NOP                                           ; Insert two NOPs after the erase
NOP                                           ; command is asserted
```

TABLE 5-1: NVM REGISTER MAP

| File Name | Addr. | Bit 15 | Bit 14 | Bit 13 | Bit 12 | Bit 11 | Bit 10 | Bit 9 | Bit 8 | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | All RESETS |
|-----------|-------|--------------|--------|--------|--------|--------|--------|-------|-------|---------------|-------------|-------|-------|-------|-------|-------|---------------------|---------------------|
| NVMCON | 0760 | WR | WREN | WRERR | — | — | — | — | TWRI | — | PROGOP<6:0> | | | | | | | 0000 0000 0000 0000 |
| NVMADR | 0762 | NVMADR<15:0> | | | | | | | | | | | | | | | | uuuu uuuu uuuu uuuu |
| NVMADRU | 0764 | — | — | — | — | — | — | — | — | NVMADR<23:16> | | | | | | | 0000 0000 uuuu uuuu | |
| NVMKEY | 0766 | — | — | — | — | — | — | — | — | KEY<7:0> | | | | | | | 0000 0000 0000 0000 | |

Legend: u = uninitialized bit; — = unimplemented bit, read as '0'

Note: Refer to the "*dsPIC30F Family Reference Manual*" (DS70046) for descriptions of register bit fields.

NOTES:

6.0 DATA EEPROM MEMORY

Note: This data sheet summarizes features of this group of dsPIC30F devices and is not intended to be a complete reference source. For more information on the CPU, peripherals, register descriptions and general device functionality, refer to the “dsPIC30F Family Reference Manual” (DS70046). For more information on the device instruction set and programming, refer to the “16-bit MCU and DSC Programmer’s Reference Manual” (DS70157).

The data EEPROM memory is readable and writable during normal operation over the entire VDD range. The data EEPROM memory is directly mapped in the program memory address space.

The four SFRs used to read and write the program Flash memory are used to access data EEPROM memory, as well. As described in [Section 5.5 “Control Registers”](#), these registers are:

- NVMCON
- NVMADR
- NVMADRU
- NVMKEY

The EEPROM data memory allows read and write of single words and 16-word blocks. When interfacing to data memory, NVMADR, in conjunction with the NVMADRU register, are used to address the EEPROM location being accessed. TBLRDL and TBLWTL instructions are used to read and write data EEPROM. The dsPIC30F devices have up to 8 Kbytes (4K words) of data EEPROM with an address range from 0x7FF000 to 0x7FFFFE.

A word write operation should be preceded by an erase of the corresponding memory location(s). The write typically requires 2 ms to complete, but the write time varies with voltage and temperature.

A program or erase operation on the data EEPROM does not stop the instruction flow. The user is responsible for waiting for the appropriate duration of time before initiating another data EEPROM write/erase operation. Attempting to read the data EEPROM while a programming or erase operation is in progress results in unspecified data.

Control bit WR initiates write operations similar to program Flash writes. This bit cannot be cleared, only set, in software. They are cleared in hardware at the completion of the write operation. The inability to clear the WR bit in software prevents the accidental or premature termination of a write operation.

The WREN bit, when set, allows a write operation. On power-up, the WREN bit is clear. The WRERR bit is set when a write operation is interrupted by a MCLR Reset or a WDT Time-out Reset during normal operation. In these situations, following Reset, the user can check the WRERR bit and rewrite the location. The address register NVMADR remains unchanged.

Note: Interrupt flag bit NVMIF in the IFS0 register is set when write is complete. It must be cleared in software.

6.1 Reading the Data EEPROM

A TBLRD instruction reads a word at the current program word address. This example uses W0 as a pointer to data EEPROM. The result is placed in register W4 as shown in [Example 6-1](#).

EXAMPLE 6-1: DATA EEPROM READ

```
MOV    #LOW_ADDR_WORD,W0 ; Init Pointer
MOV    #HIGH_ADDR_WORD,W1
MOV    W1,TBLPAG
TBLRDL [ W0 ], W4         ; read data EEPROM
```

6.2 Erasing Data EEPROM

6.2.1 ERASING A BLOCK OF DATA EEPROM

In order to erase a block of data EEPROM, the NVMADRU and NVMADR registers must initially point to the block of memory to be erased. Configure NVMCON for erasing a block of data EEPROM and set the WR and WREN bits in the NVMCON register. Setting the WR bit initiates the erase, as shown in [Example 6-2](#).

EXAMPLE 6-2: DATA EEPROM BLOCK ERASE

```
; Select data EEPROM block, WR, WREN bits
MOV    #0x4045,W0
MOV    W0,NVMCON                ; Initialize NVMCON SFR

; Start erase cycle by setting WR after writing key sequence
DISI    #5                      ; Block all interrupts with priority <7 for
                                ; next 5 instructions
MOV     #0x55,W0                ;
MOV     W0,NVMKEY               ; Write the 0x55 key
MOV     #0xAA,W1                ;
MOV     W1,NVMKEY               ; Write the 0xAA key
BSET    NVMCON,#WR              ; Initiate erase sequence
NOP
NOP

; Erase cycle will complete in 2mS. CPU is not stalled for the Data Erase Cycle
; User can poll WR bit, use NVMIF or Timer IRQ to determine erasure complete
```

6.2.2 ERASING A WORD OF DATA EEPROM

The NVMADRU and NVMADR registers must point to the block. Select WR a block of data Flash and set the WR and WREN bits in the NVMCON register. Setting the WR bit initiates the erase, as shown in [Example 6-3](#).

EXAMPLE 6-3: DATA EEPROM WORD ERASE

```
; Select data EEPROM word, WR, WREN bits
MOV     #0x4044,W0
MOV     W0,NVMCON

; Start erase cycle by setting WR after writing key sequence
DISI     #5                      ; Block all interrupts with priority <7 for
                                ; next 5 instructions
MOV      #0x55,W0                ;
MOV      W0,NVMKEY               ; Write the 0x55 key
MOV      #0xAA,W1                ;
MOV      W1,NVMKEY               ; Write the 0xAA key
BSET     NVMCON,#WR              ; Initiate erase sequence
NOP
NOP

; Erase cycle will complete in 2mS. CPU is not stalled for the Data Erase Cycle
; User can poll WR bit, use NVMIF or Timer IRQ to determine erasure complete
```


6.3 Writing to the Data EEPROM

To write an EEPROM data location, the following sequence must be followed:

1. Erase data EEPROM word.
 - a) Select word, data EEPROM erase, and set WREN bit in NVMCON register.
 - b) Write address of word to be erased into NVMADR.
 - c) Enable NVM interrupt (optional).
 - d) Write 0x55 to NVMKEY.
 - e) Write 0xAA to NVMKEY.
 - f) Set the WR bit. This begins erase cycle.
 - g) Either poll NVMIF bit or wait for NVMIF interrupt.
 - h) The WR bit is cleared when the erase cycle ends.
2. Write data word into data EEPROM write latches.
3. Program 1 data word into data EEPROM.
 - a) Select word, data EEPROM program, and set WREN bit in NVMCON register.
 - b) Enable NVM write done interrupt (optional).
 - c) Write 0x55 to NVMKEY.
 - d) Write 0xAA to NVMKEY.
 - e) Set the WR bit. This begins program cycle.
 - f) Either poll NVMIF bit or wait for NVM interrupt.
 - g) The WR bit is cleared when the write cycle ends.

The write does not initiate if the above sequence is not exactly followed (write 0x55 to NVMKEY, write 0xAA to NVMCON, then set WR bit) for each word. It is strongly recommended that interrupts be disabled during this code segment.

Additionally, the WREN bit in NVMCON must be set to enable writes. This mechanism prevents accidental writes to data EEPROM due to unexpected code execution. The WREN bit should be kept clear at all times except when updating the EEPROM. The WREN bit is not cleared by hardware.

After a write sequence has been initiated, clearing the WREN bit does not affect the current write cycle. The WR bit is inhibited from being set unless the WREN bit is set. The WREN bit must be set on a previous instruction. Both WR and WREN cannot be set with the same instruction.

At the completion of the write cycle, the WR bit is cleared in hardware and the Nonvolatile Memory Write Complete Interrupt Flag bit (NVMIF) is set. The user may either enable this interrupt or poll this bit. NVMIF must be cleared by software.

6.3.1 WRITING A WORD OF DATA EEPROM

Once the user has erased the word to be programmed, then a table write instruction is used to write one write latch, as shown in [Example 6-4](#).

6.3.2 WRITING A BLOCK OF DATA EEPROM

To write a block of data EEPROM, write to all sixteen latches first, then set the NVMCON register and program the block.

EXAMPLE 6-4: DATA EEPROM WORD WRITE

```

; Point to data memory
MOV     #LOW_ADDR_WORD,W0           ; Init pointer
MOV     #HIGH_ADDR_WORD,W1
MOV     W1,TBLPAG
MOV     #LOW(WORD),W2              ; Get data
TBLWTL  W2,[ W0]                   ; Write data
; The NVMADR captures last table access address
; Select data EEPROM for 1 word op
MOV     #0x4004,W0
MOV     W0,NVMCON

; Operate key to allow write operation
DISI     #5                        ; Block all interrupts with priority <7 for
                                   ; next 5 instructions

MOV     #0x55,W0                   ; Write the 0x55 key
MOV     W0,NVMKEY
MOV     #0xAA,W1                   ; Write the 0xAA key
MOV     W1,NVMKEY
BSET    NVMCON,#WR                 ; Initiate program sequence
NOP
NOP

; Write cycle will complete in 2mS. CPU is not stalled for the Data Write Cycle
; User can poll WR bit, use NVMIF or Timer IRQ to determine write complete

```

EXAMPLE 6-5: DATA EEPROM BLOCK WRITE

```
MOV      #LOW_ADDR_WORD,W0 ; Init pointer
MOV      #HIGH_ADDR_WORD,W1
MOV      W1,TBLPAG
MOV      #data1,W2          ; Get 1st data
TBLWTL   W2,[ W0]++         ; write data
MOV      #data2,W2          ; Get 2nd data
TBLWTL   W2,[ W0]++         ; write data
MOV      #data3,W2          ; Get 3rd data
TBLWTL   W2,[ W0]++         ; write data
MOV      #data4,W2          ; Get 4th data
TBLWTL   W2,[ W0]++         ; write data
MOV      #data5,W2          ; Get 5th data
TBLWTL   W2,[ W0]++         ; write data
MOV      #data6,W2          ; Get 6th data
TBLWTL   W2,[ W0]++         ; write data
MOV      #data7,W2          ; Get 7th data
TBLWTL   W2,[ W0]++         ; write data
MOV      #data8,W2          ; Get 8th data
TBLWTL   W2,[ W0]++         ; write data
MOV      #data9,W2          ; Get 9th data
TBLWTL   W2,[ W0]++         ; write data
MOV      #data10,W2         ; Get 10th data
TBLWTL   W2,[ W0]++         ; write data
MOV      #data11,W2         ; Get 11th data
TBLWTL   W2,[ W0]++         ; write data
MOV      #data12,W2         ; Get 12th data
TBLWTL   W2,[ W0]++         ; write data
MOV      #data13,W2         ; Get 13th data
TBLWTL   W2,[ W0]++         ; write data
MOV      #data14,W2         ; Get 14th data
TBLWTL   W2,[ W0]++         ; write data
MOV      #data15,W2         ; Get 15th data
TBLWTL   W2,[ W0]++         ; write data
MOV      #data16,W2         ; Get 16th data
TBLWTL   W2,[ W0]++         ; write data. The NVMADR captures last table access address.
MOV      #0x400A,W0         ; Select data EEPROM for multi word op
MOV      W0,NVMCON           ; Operate Key to allow program operation
DISI     #5                  ; Block all interrupts with priority <7 for
                                ; next 5 instructions

MOV      #0x55,W0            ; Write the 0x55 key
MOV      W0,NVMKEY
MOV      #0xAA,W1
MOV      W1,NVMKEY           ; Write the 0xAA key
BSET     NVMCON,#WR          ; Start write cycle
NOP
NOP
```

6.4 Write Verify

Depending on the application, good programming practice may dictate that the value written to the memory should be verified against the original value. This should be used in applications where excessive writes can stress bits near the specification limit.

6.5 Protection Against Spurious Write

There are conditions when the device may not want to write to the data EEPROM memory. To protect against spurious EEPROM writes, various mechanisms have been built-in. On power-up, the WREN bit is cleared; also, the Power-up Timer prevents EEPROM write.

The write initiate sequence and the WREN bit together help prevent an accidental write during brown-out, power glitch, or software malfunction.

7.0 I/O PORTS

Note: This data sheet summarizes features of this group of dsPIC30F devices and is not intended to be a complete reference source. For more information on the CPU, peripherals, register descriptions and general device functionality, refer to the “dsPIC30F Family Reference Manual” (DS70046).

All of the device pins (except VDD, VSS, MCLR and OSC1/CLKI) are shared between the peripherals and the parallel I/O ports.

All I/O input ports feature Schmitt Trigger inputs for improved noise immunity.

7.1 Parallel I/O (PIO) Ports

When a peripheral is enabled and the peripheral is actively driving an associated pin, the use of the pin as a general purpose output pin is disabled. The I/O pin can be read, but the output driver for the parallel port bit is disabled. If a peripheral is enabled, but the peripheral is not actively driving a pin, that pin can be driven by a port.

All port pins have three registers directly associated with the operation of the port pin. The Data Direction register (TRISx) determines whether the pin is an input or an output. If the data direction bit is a ‘1’, then the pin is an input. All port pins are defined as inputs after a Reset. Reads from the latch (LATx), read the latch.

Writes to the latch, write the latch (LATx). Reads from the port (PORTx), read the port pins and writes to the port pins, write the latch (LATx).

Any bit and its associated data and Control registers that are not valid for a particular device are disabled. That means the corresponding LATx and TRISx registers and the port pin read as zeros.

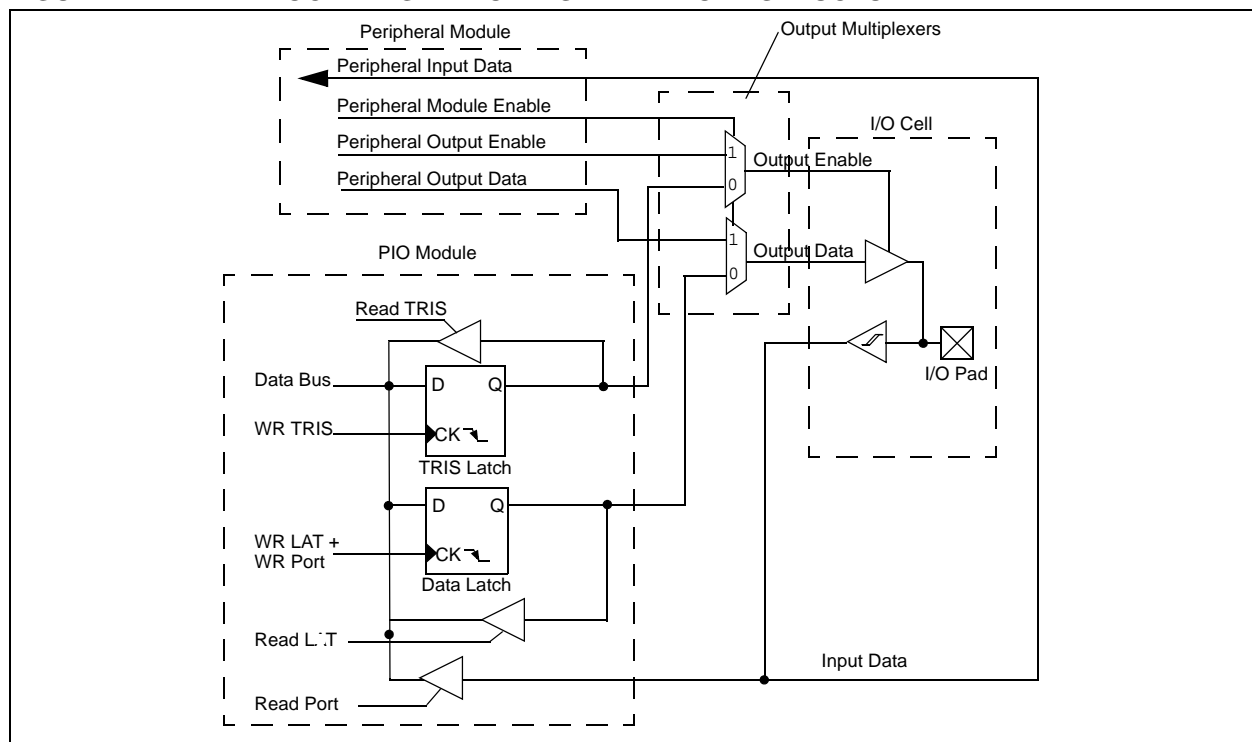
When a pin is shared with another peripheral or function that is defined as an input only, it is nevertheless regarded as a dedicated port because there is no other competing source of outputs.

A parallel I/O (PIO) port that shares a pin with a peripheral is, in general, subservient to the peripheral. The peripheral's output buffer data and control signals are provided to a pair of multiplexers. The multiplexers select whether the peripheral or the associated port has ownership of the output data and control signals of the I/O pad cell. [Figure 7-1](#) illustrates how ports are shared with other peripherals and the associated I/O cell (pad) to which they are connected.

The format of the registers for the shared ports, (PORTB, PORTC, PORTD and PORTF) are shown in [Table 7-1](#) through [Table 7-6](#).

Note: The actual bits in use vary between devices.

FIGURE 7-1: BLOCK DIAGRAM OF A SHARED PORT STRUCTURE



7.2 Configuring Analog Port Pins

The use of the ADPCFG and TRIS registers control the operation of the A/D port pins. The port pins that are desired as analog inputs must have their corresponding TRIS bit set (input). If the TRIS bit is cleared (output), the digital output level (VOH or VOL) is converted.

When the PORT register is read, all pins configured as analog input channels are read as cleared (a low level).

Pins configured as digital inputs will not convert an analog input. Analog levels on any pin that is defined as a digital input (including the ANx pins) may cause the input buffer to consume the current that exceeds device specifications.

7.2.1 I/O PORT WRITE/READ TIMING

One instruction cycle is required between a port direction change or port write operation and a read operation of the same port. Typically this instruction would be a NOP.

EXAMPLE 7-1: PORT WRITE/READ EXAMPLE

```
MOV  #0xF0, W0    ; Configure PORTB<7:4>
                  ; as inputs
MOV  W0, TRISB    ; and PORTB<3:0> as outputs
NOP               ; additional instruction
                  ; cycle
btss PORTB, #7    ; bit test RB7 and skip if
                  ; set
```

TABLE 7-1: PORTB REGISTER MAP FOR dsPIC30F2011/3012

| SFR Name | Addr. | Bit 15 | Bit 14 | Bit 13 | Bit 12 | Bit 11 | Bit 10 | Bit 9 | Bit 8 | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Reset State |
|----------|-------|--------|--------|--------|--------|--------|--------|-------|-------|--------|--------|--------|--------|--------|--------|--------|--------|---------------------|
| TRISB | 02C6 | — | — | — | — | — | — | — | — | TRISB7 | TRISB6 | TRISB5 | TRISB4 | TRISB3 | TRISB2 | TRISB1 | TRISB0 | 0000 0000 1111 1111 |
| PORTB | 02C8 | — | — | — | — | — | — | — | — | RB7 | RB6 | RB5 | RB4 | RB3 | RB2 | RB1 | RB0 | 0000 0000 0000 0000 |
| LATB | 02CB | — | — | — | — | — | — | — | — | LATB7 | LATB6 | LATB5 | LATB4 | LATB3 | LATB2 | LATB1 | LATB0 | 0000 0000 0000 0000 |

Legend: — = unimplemented bit, read as '0'

TABLE 7-2: PORTB REGISTER MAP FOR dsPIC30F2012/3013

| SFR Name | Addr. | Bit 15 | Bit 14 | Bit 13 | Bit 12 | Bit 11 | Bit 10 | Bit 9 | Bit 8 | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Reset State |
|----------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|---------------------|
| TRISB | 02C6 | — | — | — | — | — | — | TRISB9 | TRISB8 | TRISB7 | TRISB6 | TRISB5 | TRISB4 | TRISB3 | TRISB2 | TRISB1 | TRISB0 | 0000 0011 1111 1111 |
| PORTB | 02C8 | — | — | — | — | — | — | RB9 | RB8 | RB7 | RB6 | RB5 | RB4 | RB3 | RB2 | RB1 | RB0 | 0000 0000 0000 0000 |
| LATB | 02CB | — | — | — | — | — | — | LATB9 | LATB8 | LATB7 | LATB6 | LATB5 | LATB4 | LATB3 | LATB2 | LATB1 | LATB0 | 0000 0000 0000 0000 |

Legend: — = unimplemented bit, read as '0'

TABLE 7-3: PORTC REGISTER MAP FOR dsPIC30F2011/2012/3012/3013

| SFR Name | Addr. | Bit 15 | Bit 14 | Bit 13 | Bit 12 | Bit 11 | Bit 10 | Bit 9 | Bit 8 | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Reset State |
|----------|-------|---------|---------|---------|--------|--------|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|---------------------|
| TRISC | 02CC | TRISC15 | TRISC14 | TRISC13 | — | — | — | — | — | — | — | — | — | — | — | — | — | 1110 0000 0000 0000 |
| PORTC | 02CE | RC15 | RC14 | RC13 | — | — | — | — | — | — | — | — | — | — | — | — | — | 0000 0000 0000 0000 |
| LATC | 02D0 | LATC15 | LATC14 | LATC13 | — | — | — | — | — | — | — | — | — | — | — | — | — | 0000 0000 0000 0000 |

Legend: — = unimplemented bit, read as '0'

TABLE 7-4: PORTD REGISTER MAP FOR dsPIC30F2011/3012

| SFR Name | Addr. | Bit 15 | Bit 14 | Bit 13 | Bit 12 | Bit 11 | Bit 10 | Bit 9 | Bit 8 | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Reset State |
|----------|-------|--------|--------|--------|--------|--------|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|---------------------|
| TRISD | 02D2 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | TRISD0 | 0000 0000 0000 0001 |
| PORTD | 02D4 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | RD0 | 0000 0000 0000 0000 |
| LATD | 02D6 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | LATD0 | 0000 0000 0000 0000 |

Legend: — = unimplemented bit, read as '0'

TABLE 7-5: PORTD REGISTER MAP FOR dsPIC30F2012/3013

| SFR Name | Addr. | Bit 15 | Bit 14 | Bit 13 | Bit 12 | Bit 11 | Bit 10 | Bit 9 | Bit 8 | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Reset State |
|----------|-------|--------|--------|--------|--------|--------|--------|--------|--------|-------|-------|-------|-------|-------|-------|-------|-------|---------------------|
| TRISD | 02D2 | — | — | — | — | — | — | TRISD9 | TRISD8 | — | — | — | — | — | — | — | — | 0000 0011 0000 0000 |
| PORTD | 02D4 | — | — | — | — | — | — | RD9 | RD8 | — | — | — | — | — | — | — | — | 0000 0000 0000 0000 |
| LATD | 02D6 | — | — | — | — | — | — | LATD9 | LATD8 | — | — | — | — | — | — | — | — | 0000 0000 0000 0000 |

Legend: — = unimplemented bit, read as '0'

TABLE 7-6: PORTF REGISTER MAP FOR dsPIC30F2012/3013

| SFR Name | Addr. | Bit 15 | Bit 14 | Bit 13 | Bit 12 | Bit 11 | Bit 10 | Bit 9 | Bit 8 | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Reset State |
|----------|-------|--------|--------|--------|--------|--------|--------|-------|-------|-------|--------|--------|--------|--------|--------|-------|-------|---------------------|
| TRISF | 02DE | — | — | — | — | — | — | — | — | — | TRISF6 | TRISF5 | TRISF4 | TRISF3 | TRISF2 | — | — | 0000 0000 0111 1100 |
| PORTF | 02E0 | — | — | — | — | — | — | — | — | — | RF6 | RF5 | RF4 | RF3 | RF2 | — | — | 0000 0000 0000 0000 |
| LATF | 02E2 | — | — | — | — | — | — | — | — | — | LATF6 | LATF5 | LATF4 | LATF3 | LATF2 | — | — | 0000 0000 0000 0000 |

Legend: — = unimplemented bit, read as '0'

Note: The dsPIC30F2011/3012 devices do not have TRISF, PORTF, or LATF.

dsPIC30F2011/2012/3012/3013

7.3 Input Change Notification Module

The input change notification module provides the dsPIC30F devices the ability to generate interrupt requests to the processor, in response to a change of state on selected input pins. This module is capable of detecting input change of states even in Sleep mode, when the clocks are disabled. There are up to 10 external signals (CN0 through CN7, CN17 and CN18) that may be selected (enabled) for generating an interrupt request on a change of state.

TABLE 7-7: INPUT CHANGE NOTIFICATION REGISTER MAP FOR dsPIC30F2011/3012 (BITS 7-0)

| SFR Name | Address | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Reset State |
|----------|---------|--------|--------|--------|--------|--------|--------|--------|--------|---------------------|
| CNEN1 | 00C0 | CN7IE | CN6IE | CN5IE | CN4IE | CN3IE | CN2IE | CN1IE | CN0IE | 0000 0000 0000 0000 |
| CNEN2 | 00C2 | — | — | — | — | — | — | — | — | 0000 0000 0000 0000 |
| CNPU1 | 00C4 | CN7PUE | CN6PUE | CN5PUE | CN4PUE | CN3PUE | CN2PUE | CN1PUE | CN0PUE | 0000 0000 0000 0000 |
| CNPU2 | 00C6 | — | — | — | — | — | — | — | — | 0000 0000 0000 0000 |

Legend: — = unimplemented bit, read as '0'

TABLE 7-8: INPUT CHANGE NOTIFICATION REGISTER MAP FOR dsPIC30F2012/3013 (BITS 7-0)

| SFR Name | Address | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Reset State |
|----------|---------|--------|--------|--------|--------|--------|---------|---------|--------|---------------------|
| CNEN1 | 00C0 | CN7IE | CN6IE | CN5IE | CN4IE | CN3IE | CN2IE | CN1IE | CN0IE | 0000 0000 0000 0000 |
| CNEN2 | 00C2 | — | — | — | — | — | CN18IE | CN17IE | — | 0000 0000 0000 0000 |
| CNPU1 | 00C4 | CN7PUE | CN6PUE | CN5PUE | CN4PUE | CN3PUE | CN2PUE | CN1PUE | CN0PUE | 0000 0000 0000 0000 |
| CNPU2 | 00C6 | — | — | — | — | — | CN18PUE | CN17PUE | — | 0000 0000 0000 0000 |

Legend: — = unimplemented bit, read as '0'

Note: Refer to the "dsPIC30F Family Reference Manual" (DS70046) for descriptions of register bit fields.

NOTES:

8.0 INTERRUPTS

Note: This data sheet summarizes features of this group of dsPIC30F devices and is not intended to be a complete reference source. For more information on the CPU, peripherals, register descriptions and general device functionality, refer to the “dsPIC30F Family Reference Manual” (DS70046). For more information on the device instruction set and programming, refer to the “16-bit MCU and DSC Programmer’s Reference Manual” (DS70157).

The dsPIC30F sensor family has up to 21 interrupt sources and 4 processor exceptions (traps) which must be arbitrated based on a priority scheme.

The CPU is responsible for reading the Interrupt Vector Table (IVT) and transferring the address contained in the interrupt vector to the program counter. The interrupt vector is transferred from the program data bus into the program counter via a 24-bit wide multiplexer on the input of the program counter.

The Interrupt Vector Table (IVT) and Alternate Interrupt Vector Table (AIVT) are placed near the beginning of program memory (0x000004). The IVT and AIVT are shown in [Figure 8-1](#).

The interrupt controller is responsible for pre-processing the interrupts and processor exceptions before they are presented to the processor core. The peripheral interrupts and traps are enabled, prioritized and controlled using centralized Special Function Registers (SFRs):

- IFS0<15:0>, IFS1<15:0>, IFS2<15:0>
All interrupt request flags are maintained in these three registers. The flags are set by their respective peripherals or external signals and they are cleared via software.
- IEC0<15:0>, IEC1<15:0>, IEC2<15:0>
All interrupt enable control bits are maintained in these three registers. These control bits are used to individually enable interrupts from the peripherals or external signals.
- IPC0<15:0> through IPC10<7:0>
The user assignable priority level associated with each of these 41 interrupts is held centrally in these eleven registers.
- IPL<3:0>
The current CPU priority level is explicitly stored in the IPL bits. IPL<3> is present in the CORCON register, whereas IPL<2:0> are present in the STATUS register (SR) in the processor core.

- INTCON1<15:0>, INTCON2<15:0>
Global interrupt control functions are derived from these two registers. INTCON1 contains the control and status flags for the processor exceptions. The INTCON2 register controls the external interrupt request signal behavior and the use of the alternate vector table.

Note: Interrupt flag bits get set when an interrupt condition occurs, regardless of the state of its corresponding enable bit. User software should ensure the appropriate interrupt flag bits are clear prior to enabling an interrupt.

All interrupt sources can be user assigned to one of 7 priority levels, 1 through 7, through the IPCx registers. Each interrupt source is associated with an interrupt vector, as shown in [Table 8-1](#). Levels 7 and 1 represent the highest and lowest maskable priorities, respectively.

Note: Assigning a priority level of ‘0’ to an interrupt source is equivalent to disabling that interrupt.

If the NSTDIS bit (INTCON1<15>) is set, nesting of interrupts is prevented. Thus, if an interrupt is currently being serviced, processing of a new interrupt is prevented even if the new interrupt is of higher priority than the one currently being serviced.

Note: The IPL bits become read-only whenever the NSTDIS bit has been set to ‘1’.

Certain interrupts have specialized control bits for features like edge or level triggered interrupts, interrupt-on-change, etc. Control of these features remains within the peripheral module which generates the interrupt.

The DISI instruction can be used to disable the processing of interrupts of priorities 6 and lower for a certain number of instructions, during which the DISI bit (INTCON2<14>) remains set.

When an interrupt is serviced, the PC is loaded with the address stored in the vector location in program memory that corresponds to the interrupt. There are 63 different vectors within the IVT (refer to [Table 8-1](#)). These vectors are contained in locations 0x000004 through 0x0000FE of program memory (refer to [Table 8-1](#)). These locations contain 24-bit addresses, and in order to preserve robustness, an address error trap takes place if the PC attempts to fetch any of these words during normal execution. This prevents execution of random data as a result of accidentally decrementing a PC into vector space, accidentally mapping a data space address into vector space, or the PC rolling over to 0x000000 after reaching the end of implemented program memory space. Execution of a GOTO instruction to this vector space also generates an address error trap.

8.1 Interrupt Priority

The user-assignable interrupt priority bits (IP<2:0>) for each individual interrupt source are located in the LS 3 bits of each nibble within the IPCx register(s). Bit 3 of each nibble is not used and is read as a '0'. These bits define the priority level assigned to a particular interrupt by the user.

Note: The user-assignable priority levels start at 0 as the lowest priority and level 7 as the highest priority.

Natural Order Priority is determined by the position of an interrupt in the vector table, and only affects interrupt operation when multiple interrupts with the same user-assigned priority become pending at the same time.

Table 8-1 lists the interrupt numbers and interrupt sources for the dsPIC30F2011/2012/3012/3013 devices and their associated vector numbers.

Note 1: The natural order priority scheme has 0 as the highest priority and 53 as the lowest priority.

2: The natural order priority number is the same as the INT number.

The ability for the user to assign every interrupt to one of seven priority levels means that the user can assign a very high overall priority level to an interrupt with a low natural order priority. For example, the PLVD (Low Voltage Detect) can be given a priority of 7. The INT0 (External Interrupt 0) may be assigned to priority level 1, thus giving it a very low effective priority.

TABLE 8-1: INTERRUPT VECTOR TABLE

| Interrupt Number | Vector Number | Interrupt Source |
|--------------------------------|---------------|--|
| Highest Natural Order Priority | | |
| 0 | 8 | INT0 – External Interrupt 0 |
| 1 | 9 | IC1 – Input Capture 1 |
| 2 | 10 | OC1 – Output Compare 1 |
| 3 | 11 | T1 – Timer 1 |
| 4 | 12 | IC2 – Input Capture 2 |
| 5 | 13 | OC2 – Output Compare 2 |
| 6 | 14 | T2 – Timer2 |
| 7 | 15 | T3 – Timer3 |
| 8 | 16 | SPI1 |
| 9 | 17 | U1RX – UART1 Receiver |
| 10 | 18 | U1TX – UART1 Transmitter |
| 11 | 19 | ADC – ADC Convert Done |
| 12 | 20 | NVM – NVM Write Complete |
| 13 | 21 | SI2C – I ² C™ Slave Interrupt |
| 14 | 22 | MI2C – I ² C Master Interrupt |
| 15 | 23 | Input Change Interrupt |
| 16 | 24 | INT1 – External Interrupt 1 |
| 17-22 | 25-30 | Reserved |
| 23 | 31 | INT2 – External Interrupt 2 |
| 24 | 32 | U2RX ⁽¹⁾ – UART2 Receiver |
| 25 | 33 | U2TX ⁽¹⁾ – UART2 Transmitter |
| 26-41 | 34-49 | Reserved |
| 42 | 50 | LVD – Low-Voltage Detect |
| 43-53 | 51-61 | Reserved |
| Lowest Natural Order Priority | | |

Note 1: Only the dsPIC30F3013 has UART2 and the U2RX, U2TX interrupts. These locations are reserved for the dsPIC30F2011/2012/3012.

8.2 Reset Sequence

A Reset is not a true exception because the interrupt controller is not involved in the Reset process. The processor initializes its registers in response to a Reset which forces the PC to zero. The processor then begins program execution at location 0x000000. A `GOTO` instruction is stored in the first program memory location immediately followed by the address target for the `GOTO` instruction. The processor executes the `GOTO` to the specified address and then begins operation at the specified target (start) address.

8.2.1 RESET SOURCES

In addition to external Reset and Power-on Reset (POR), there are six sources of error conditions which 'trap' to the Reset vector.

- **Watchdog Time-out:**
The watchdog has timed out, indicating that the processor is no longer executing the correct flow of code.
- **Uninitialized W Register Trap:**
An attempt to use an uninitialized W register as an Address Pointer causes a Reset.
- **Illegal Instruction Trap:**
Attempted execution of any unused opcodes results in an illegal instruction trap. Note that a fetch of an illegal instruction does not result in an illegal instruction trap if that instruction is flushed prior to execution due to a flow change.
- **Brown-out Reset (BOR):**
A momentary dip in the power supply to the device has been detected which may result in malfunction.
- **Trap Lockout:**
Occurrence of multiple trap conditions simultaneously causes a Reset.

8.3 Traps

Traps can be considered as non-maskable interrupts indicating a software or hardware error, which adhere to a predefined priority as shown in [Figure 8-1](#). They are intended to provide the user a means to correct erroneous operation during debug and when operating within the application.

Note: If the user does not intend to take corrective action in the event of a trap error condition, these vectors must be loaded with the address of a default handler that contains the `RESET` instruction. If, on the other hand, one of the vectors containing an invalid address is called, an address error trap is generated.

Note that many of these trap conditions can only be detected when they occur. Consequently, the questionable instruction is allowed to complete prior to trap exception processing. If the user chooses to recover from the error, the result of the erroneous action that caused the trap may have to be corrected.

There are eight fixed priority levels for traps: Level 8 through Level 15, which implies that the IPL3 is always set during processing of a trap.

If the user is not currently executing a trap, and he sets the IPL<3:0> bits to a value of '0111' (Level 7), then all interrupts are disabled, but traps can still be processed.

8.3.1 TRAP SOURCES

The following traps are provided with increasing priority. However, since all traps can be nested, priority has little effect.

Math Error Trap:

The math error trap executes under the following four circumstances:

1. If an attempt is made to divide by zero, the divide operation is aborted on a cycle boundary and the trap is taken.
2. If enabled, a math error trap is taken when an arithmetic operation on either accumulator A or B causes an overflow from bit 31 and the accumulator guard bits are not utilized.
3. If enabled, a math error trap is taken when an arithmetic operation on either accumulator A or B causes a catastrophic overflow from bit 39 and all saturation is disabled.
4. If the shift amount specified in a shift instruction is greater than the maximum allowed shift amount, a trap occurs.

Address Error Trap:

This trap is initiated when any of the following circumstances occurs:

1. A misaligned data word access is attempted.
2. A data fetch from our unimplemented data memory location is attempted.
3. A data access of an unimplemented program memory location is attempted.
4. An instruction fetch from vector space is attempted.

| |
|--|
| <p>Note: In the MAC class of instructions, wherein the data space is split into X and Y data space, unimplemented X space includes all of Y space, and unimplemented Y space includes all of X space.</p> |
|--|

5. Execution of a “BRA #literal” instruction or a “GOTO #literal” instruction, where *literal* is an unimplemented program memory address.
6. Executing instructions after modifying the PC to point the unimplemented program memory addresses. The PC may be modified by loading a value into the stack and executing a RETURN instruction.

Stack Error Trap:

This trap is initiated under the following conditions:

- The Stack Pointer is loaded with a value which is greater than the (user programmable) limit value written into the SPLIM register (stack overflow).
- The Stack Pointer is loaded with a value which is less than 0x0800 (simple stack underflow).

Oscillator Fail Trap:

This trap is initiated if the external oscillator fails and operation becomes reliant on an internal RC backup.

8.3.2 HARD AND SOFT TRAPS

It is possible that multiple traps can become active within the same cycle (e.g., a misaligned word stack write to an overflowed address). In such a case, the fixed priority shown in [Figure 8-2](#) is implemented, which may require the user to check if other traps are pending, in order to completely correct the Fault.

Soft traps include exceptions of priority level 8 through level 11, inclusive. The arithmetic error trap (level 11) falls into this category of traps.

Hard traps include exceptions of priority level 12 through level 15, inclusive. The address error (level 12), stack error (level 13) and oscillator error (level 14) traps fall into this category.

Each hard trap that occurs must be acknowledged before code execution of any type can continue. If a lower priority hard trap occurs while a higher priority trap is pending, acknowledged, or is being processed, a hard trap conflict occurs.

The device is automatically Reset in a hard trap conflict condition. The TRAPR Status bit (RCON<15>) is set when the Reset occurs, so that the condition may be detected in software.

FIGURE 8-1: TRAP VECTORS

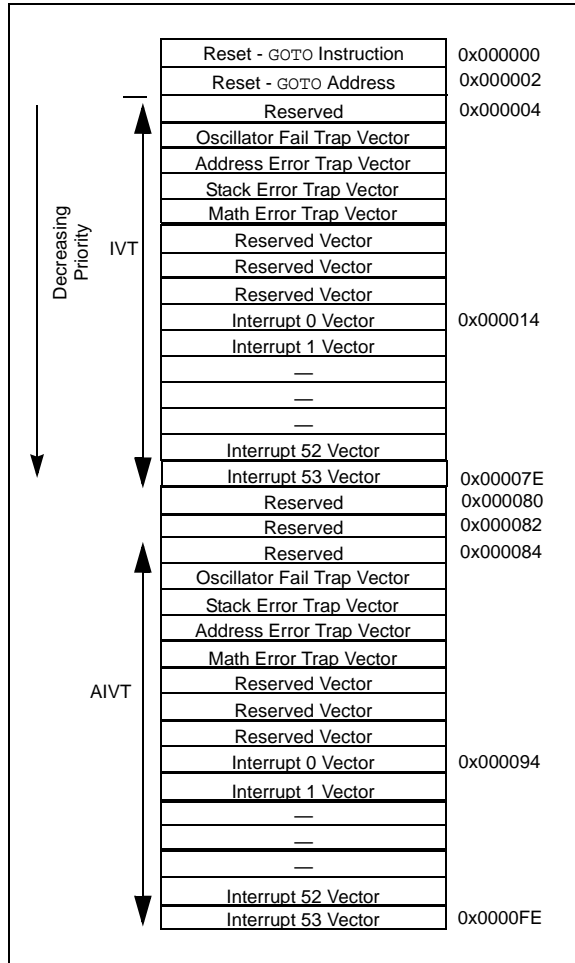
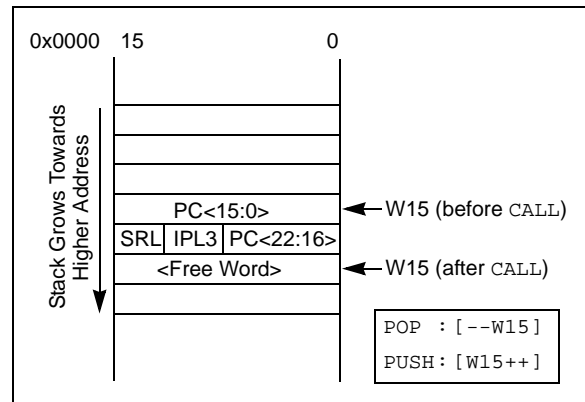


FIGURE 8-2: INTERRUPT STACK FRAME



- Note 1:** The user can always lower the priority level by writing a new value into SR. The Interrupt Service Routine must clear the interrupt flag bits in the IFSx register before lowering the processor interrupt priority, in order to avoid recursive interrupts.
- 2:** The IPL3 bit (CORCON<3>) is always clear when interrupts are being processed. It is set only during execution of traps.

The RETFIE (return from interrupt) instruction unstacks the program counter and STATUS registers to return the processor to its state prior to the interrupt sequence.

8.4 Interrupt Sequence

All interrupt event flags are sampled in the beginning of each instruction cycle by the IFSx registers. A pending Interrupt Request (IRQ) is indicated by the flag bit being equal to a '1' in an IFSx register. The IRQ causes an interrupt to occur if the corresponding bit in the Interrupt Enable (IECx) register is set. For the remainder of the instruction cycle, the priorities of all pending interrupt requests are evaluated.

If there is a pending IRQ with a priority level greater than the current processor priority level in the IPL bits, the processor is interrupted.

The processor then stacks the current program counter and the low byte of the processor STATUS register (SRL), as shown in Figure 8-2. The low byte of the STATUS register contains the processor priority level at the time prior to the beginning of the interrupt cycle. The processor then loads the priority level for this interrupt into the STATUS register. This action disables all lower priority interrupts until the completion of the Interrupt Service Routine (ISR).

8.5 Alternate Vector Table

In program memory, the Interrupt Vector Table (IVT) is followed by the Alternate Interrupt Vector Table (AIVT), as shown in Figure 8-1. Access to the alternate vector table is provided by the ALTIVT bit in the INTCON2 register. If the ALTIVT bit is set, all interrupt and exception processes use the alternate vectors instead of the default vectors. The alternate vectors are organized in the same manner as the default vectors. The AIVT supports emulation and debugging efforts by providing a means to switch between an application and a support environment without requiring the interrupt vectors to be reprogrammed. This feature also enables switching between applications for evaluation of different software algorithms at run time.

If the AIVT is not required, the program memory allocated to the AIVT may be used for other purposes. AIVT is not a protected section and may be freely programmed by the user.

8.6 Fast Context Saving

A context saving option is available using shadow registers. Shadow registers are provided for the DC, N, OV, Z and C bits in SR, and the registers W0 through W3. The shadows are only one level deep. The shadow registers are accessible using the `PUSH.S` and `POP.S` instructions only.

When the processor vectors to an interrupt, the `PUSH.S` instruction can be used to store the current value of the aforementioned registers into their respective shadow registers.

If an ISR of a certain priority uses the `PUSH.S` and `POP.S` instructions for fast context saving, then a higher priority ISR should not include the same instructions. Users must save the key registers in software during a lower priority interrupt if the higher priority ISR uses fast context saving.

8.7 External Interrupt Requests

The interrupt controller supports three external interrupt request signals, INT0-INT2. These inputs are edge sensitive; they require a low-to-high or a high-to-low transition to generate an interrupt request. The INTCON2 register has three bits, INT0EP-INT2EP, that select the polarity of the edge detection circuitry.

8.8 Wake-up from Sleep and Idle

The interrupt controller may be used to wake-up the processor from either Sleep or Idle modes, if Sleep or Idle mode is active when the interrupt is generated.

If an enabled interrupt request of sufficient priority is received by the interrupt controller, then the standard interrupt request is presented to the processor. At the same time, the processor wakes up from Sleep or Idle and begins execution of the ISR needed to process the interrupt request.

TABLE 8-2: dsPIC30F2011/2012/3012 INTERRUPT CONTROLLER REGISTER MAP

| SFR Name | ADR | Bit 15 | Bit 14 | Bit 13 | Bit 12 | Bit 11 | Bit 10 | Bit 9 | Bit 8 | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Reset State |
|----------|------|--------|-------------|--------|--------|--------|-------------|--------|--------|--------|-------------|-------|---------|---------|-------------|---------|--------|---------------------|
| INTCON1 | 0080 | NSTDIS | — | — | — | — | OVATE | OVATE | COVTE | — | — | — | MATHERR | ADDRERR | STKERR | OSCFail | — | 0000 0000 0000 0000 |
| INTCON2 | 0082 | ALTIVT | DISI | — | — | — | — | — | — | — | — | — | — | — | INT2EP | INT1EP | INT0EP | 0000 0000 0000 0000 |
| IFS0 | 0084 | CNIF | MI2CIF | SI2CIF | NVMIF | ADIF | U1TXIF | U1RXIF | SPI1IF | T3IF | T2IF | OC2IF | IC2IF | T1IF | OC1IF | IC1IF | INT0IF | 0000 0000 0000 0000 |
| IFS1 | 0086 | — | — | — | — | — | — | — | — | INT2IF | — | — | — | — | — | — | INT1IF | 0000 0000 0000 0000 |
| IFS2 | 0088 | — | — | — | — | — | LVDIF | — | — | — | — | — | — | — | — | — | — | 0000 0000 0000 0000 |
| IEC0 | 008C | CNIE | MI2CIE | SI2CIE | NVMIE | ADIE | U1TXIE | U1RXIE | SPI1IE | T3IE | T2IE | OC2IE | IC2IE | T1IE | OC1IE | IC1IE | INT0IE | 0000 0000 0000 0000 |
| IEC1 | 008E | — | — | — | — | — | — | — | — | INT2IE | — | — | — | — | — | — | INT1IE | 0000 0000 0000 0000 |
| IEC2 | 0090 | — | — | — | — | — | LVDIE | — | — | — | — | — | — | — | — | — | — | 0000 0000 0000 0000 |
| IPC0 | 0094 | — | T1IP<2:0> | | | — | OC1IP<2:0> | | | — | IC1IP<2:0> | | | — | INT0IP<2:0> | | | 0100 0100 0100 0100 |
| IPC1 | 0096 | — | T31P<2:0> | | | — | T2IP<2:0> | | | — | OC2IP<2:0> | | | — | IC2IP<2:0> | | | 0100 0100 0100 0100 |
| IPC2 | 0098 | — | ADIP<2:0> | | | — | U1TXIP<2:0> | | | — | U1RXIP<2:0> | | | — | SPI1IP<2:0> | | | 0100 0100 0100 0100 |
| IPC3 | 009A | — | CNIP<2:0> | | | — | MI2CIP<2:0> | | | — | SI2CIP<2:0> | | | — | NVMIP<2:0> | | | 0100 0100 0100 0100 |
| IPC4 | 009C | — | — | — | — | — | — | — | — | — | — | — | — | — | INT1IP<2:0> | | | 0000 0000 0000 0100 |
| IPC5 | 009E | — | INT2IP<2:0> | | | — | — | — | — | — | — | — | — | — | — | — | — | 0100 0000 0000 0000 |
| IPC6 | 00A0 | — | — | — | — | — | — | — | — | — | 1 | 0 | 0 | — | 1 | 0 | 0 | 0000 0000 0100 0100 |
| IPC7 | 00A2 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 0000 0000 0000 0000 |
| IPC8 | 00A4 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 0000 0000 0000 0000 |
| IPC9 | 00A6 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 0000 0000 0000 0000 |
| IPC10 | 00A8 | — | — | — | — | — | LVDIP<2:0> | | | — | — | — | — | — | — | — | — | 0000 0100 0000 0000 |

Legend: u = uninitialized bit; — = unimplemented bit, read as '0'

Note: Refer to the "dsPIC30F Family Reference Manual" (DS70046) for descriptions of register bit fields.

TABLE 8-3: dsPIC30F3013 INTERRUPT CONTROLLER REGISTER MAP

| SFR Name | ADR | Bit 15 | Bit 14 | Bit 13 | Bit 12 | Bit 11 | Bit 10 | Bit 9 | Bit 8 | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Reset State |
|----------|------|--------|-------------|--------|--------|--------|-------------|--------|--------|--------|-------------|-------|---------|---------|-------------|---------|--------|---------------------|
| INTCON1 | 0080 | NSTDIS | — | — | — | — | OVATE | OVATE | COVTE | — | — | — | MATHERR | ADDRERR | STKERR | OSCFail | — | 0000 0000 0000 0000 |
| INTCON2 | 0082 | ALTIVT | DISI | — | — | — | — | — | — | — | — | — | — | — | INT2EP | INT1EP | INT0EP | 0000 0000 0000 0000 |
| IFS0 | 0084 | CNIF | MI2CIF | SI2CIF | NVMIF | ADIF | U1TXIF | U1RXIF | SPI1IF | T3IF | T2IF | OC2IF | IC2IF | T1IF | OC1IF | IC1IF | INT0IF | 0000 0000 0000 0000 |
| IFS1 | 0086 | — | — | — | — | — | — | U2TXIF | U2RXIF | INT2IF | — | — | — | — | — | — | INT1IF | 0000 0000 0000 0000 |
| IFS2 | 0088 | — | — | — | — | — | LVDIF | — | — | — | — | — | — | — | — | — | — | 0000 0000 0000 0000 |
| IEC0 | 008C | CNIE | MI2CIE | SI2CIE | NVMIE | ADIE | U1TXIE | U1RXIE | SPI1IE | T3IE | T2IE | OC2IE | IC2IE | T1IE | OC1IE | IC1IE | INT0IE | 0000 0000 0000 0000 |
| IEC1 | 008E | — | — | — | — | — | — | U2TXIE | U2RXIE | INT2IE | — | — | — | — | — | — | INT1IE | 0000 0000 0000 0000 |
| IEC2 | 0090 | — | — | — | — | — | LVDIE | — | — | — | — | — | — | — | — | — | — | 0000 0000 0000 0000 |
| IPC0 | 0094 | — | T1IP<2:0> | | | — | OC1IP<2:0> | | | — | IC1IP<2:0> | | | — | INT0IP<2:0> | | | 0100 0100 0100 0100 |
| IPC1 | 0096 | — | T31P<2:0> | | | — | T2IP<2:0> | | | — | OC2IP<2:0> | | | — | IC2IP<2:0> | | | 0100 0100 0100 0100 |
| IPC2 | 0098 | — | ADIP<2:0> | | | — | U1TXIP<2:0> | | | — | U1RXIP<2:0> | | | — | SPI1IP<2:0> | | | 0100 0100 0100 0100 |
| IPC3 | 009A | — | CNIP<2:0> | | | — | MI2CIP<2:0> | | | — | SI2CIP<2:0> | | | — | NVMIP<2:0> | | | 0100 0100 0100 0100 |
| IPC4 | 009C | — | — | — | — | — | — | — | — | — | — | — | — | — | INT1IP<2:0> | | | 0000 0000 0000 0100 |
| IPC5 | 009E | — | INT2IP<2:0> | | | — | — | — | — | — | — | — | — | — | — | — | — | 0100 0000 0000 0000 |
| IPC6 | 00A0 | — | — | — | — | — | — | — | — | — | U2TXIP<2:0> | | | — | U2RXIP<2:0> | | | 0000 0000 0100 0100 |
| IPC7 | 00A2 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 0000 0000 0000 0000 |
| IPC8 | 00A4 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 0000 0000 0000 0000 |
| IPC9 | 00A6 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 0000 0000 0000 0000 |
| IPC10 | 00A8 | — | — | — | — | — | LVDIP<2:0> | | | — | — | — | — | — | — | — | — | 0000 0100 0000 0000 |

Legend: u = uninitialized bit; — = unimplemented bit, read as '0'

Note: Refer to the "dsPIC30F Family Reference Manual" (DS70046) for descriptions of register bit fields.

9.0 TIMER1 MODULE

Note: This data sheet summarizes features of this group of dsPIC30F devices and is not intended to be a complete reference source. For more information on the CPU, peripherals, register descriptions and general device functionality, refer to the “*dsPIC30F Family Reference Manual*” (DS70046).

This section describes the 16-bit general purpose Timer1 module and associated operational modes. **Figure 9-1** depicts the simplified block diagram of the 16-bit Timer1 module. The following sections provide detailed descriptions including setup and Control registers, along with associated block diagrams for the operational modes of the timers.

The Timer1 module is a 16-bit timer that serves as the time counter for the real-time clock or operates as a free-running interval timer/counter. The 16-bit timer has the following modes:

- 16-bit Timer
- 16-bit Synchronous Counter
- 16-bit Asynchronous Counter

These operational characteristics are supported:

- Timer gate operation
- Selectable prescaler settings
- Timer operation during CPU Idle and Sleep modes
- Interrupt on 16-bit Period register match or falling edge of external gate signal

These operating modes are determined by setting the appropriate bit(s) in the 16-bit SFR, T1CON. [Figure 9-1](#) presents a block diagram of the 16-bit timer module.

16-bit Timer Mode: In the 16-bit Timer mode, the timer increments on every instruction cycle up to a match value preloaded into the Period register PR1, then resets to '0' and continues to count.

When the CPU goes into the Idle mode, the timer stops incrementing unless the TSIDL (T1CON<3>) bit = 0. If TSIDL = 1, the timer module logic resumes the incrementing sequence on termination of CPU Idle mode.

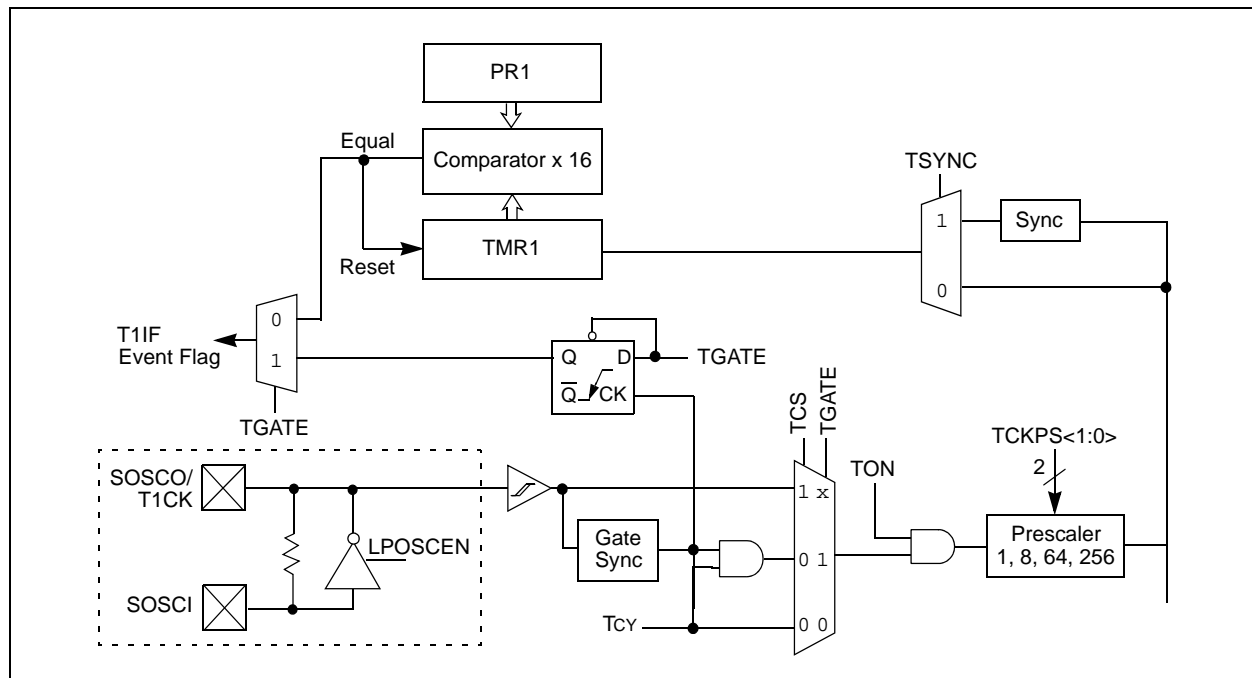
16-bit Synchronous Counter Mode: In the 16-bit Synchronous Counter mode, the timer increments on the rising edge of the applied external clock signal which is synchronized with the internal phase clocks. The timer counts up to a match value preloaded in PR1, then resets to '0' and continues.

When the CPU goes into the Idle mode, the timer stops incrementing unless the respective TSIDL bit = 0. If TSIDL = 1, the timer module logic resumes the incrementing sequence upon termination of the CPU Idle mode.

16-bit Asynchronous Counter Mode: In the 16-bit Asynchronous Counter mode, the timer increments on every rising edge of the applied external clock signal. The timer counts up to a match value preloaded in PR1, then resets to '0' and continues.

When the timer is configured for the Asynchronous mode of operation and the CPU goes into the Idle mode, the timer stops incrementing if $TSIDL = 1$.

FIGURE 9-1: 16-BIT TIMER1 MODULE BLOCK DIAGRAM



9.1 Timer Gate Operation

The 16-bit timer can be placed in the Gated Time Accumulation mode. This mode allows the internal Tcy to increment the respective timer when the gate input signal (T1CK pin) is asserted high. Control bit, TGATE (T1CON<6>), must be set to enable this mode. The timer must be enabled (TON = 1) and the timer clock source set to internal (TCS = 0).

When the CPU goes into Idle mode, the timer stops incrementing unless TSIDL = 0. If TSIDL = 1, the timer resumes the incrementing sequence upon termination of the CPU Idle mode.

9.2 Timer Prescaler

The input clock (Fosc/4 or external clock) to the 16-bit Timer has a prescale option of 1:1, 1:8, 1:64 and 1:256, selected by control bits, TCKPS<1:0> (T1CON<5:4>). The prescaler counter is cleared when any of the following occurs:

- A write to the TMR1 register
- A write to the T1CON register
- A device Reset, such as a POR and BOR

However, if the timer is disabled (TON = 0), then the timer prescaler cannot be reset since the prescaler clock is halted.

The TMR1 register is not cleared when the T1CON register is written. It is cleared by writing to the TMR1 register.

9.3 Timer Operation During Sleep Mode

The timer operates during CPU Sleep mode, if:

- The timer module is enabled (TON = 1), and
- The timer clock source is selected as external (TCS = 1), and
- The TSYNC bit (T1CON<2>) is asserted to a logic '0' which defines the external clock source as asynchronous.

When all three conditions are true, the timer continues to count up to the Period register and be reset to 0x0000.

When a match between the timer and the Period register occurs, an interrupt can be generated if the respective timer interrupt enable bit is asserted.

9.4 Timer Interrupt

The 16-bit timer has the ability to generate an interrupt-on-period match. When the timer count matches the Period register, the T1IF bit is asserted and an interrupt is generated, if enabled. The T1IF bit must be cleared in software. The timer interrupt flag, T1IF, is located in the IFS0 Control register in the interrupt controller.

When the Gated Time Accumulation mode is enabled, an interrupt is also generated on the falling edge of the gate signal (at the end of the accumulation cycle).

Enabling an interrupt is accomplished via the respective timer interrupt enable bit, T1IE. The timer interrupt enable bit is located in the IEC0 Control register in the interrupt controller.

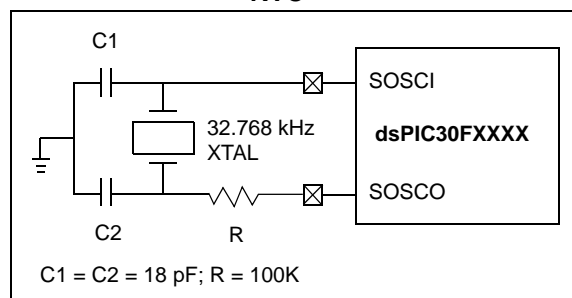
9.5 Real-Time Clock

Timer1, when operating in Real-Time Clock (RTC) mode, provides time of day and event time-stamping capabilities. Key operational features of the RTC are:

- Operation from 32 kHz LP oscillator
- 8-bit prescaler
- Low power
- Real-Time Clock interrupts

These operating modes are determined by setting the appropriate bit(s) in the T1CON register.

FIGURE 9-2: RECOMMENDED COMPONENTS FOR TIMER1 LP OSCILLATOR RTC



9.5.1 RTC OSCILLATOR OPERATION

When the TON = 1, TCS = 1 and TGATE = 0, the timer increments on the rising edge of the 32 kHz LP oscillator output signal, up to the value specified in the Period register and is then reset to '0'.

The TSYNC bit must be asserted to a logic '0' (Asynchronous mode) for correct operation.

Enabling the LPOSCEN bit (OSCCON<1>) disables the normal Timer and Counter modes and enables a timer carry-out wake-up event.

When the CPU enters Sleep mode, the RTC continues to operate, provided the 32 kHz external crystal oscillator is active and the control bits have not been changed. The TSIDL bit should be cleared to '0' in order for RTC to continue operation in Idle mode.

9.5.2 RTC INTERRUPTS

When an interrupt event occurs, the respective interrupt flag, T1IF, is asserted and an interrupt is generated if enabled. The T1IF bit must be cleared in software. The respective Timer interrupt flag, T1IF, is located in the IFS0 register in the interrupt controller.

Enabling an interrupt is accomplished via the respective timer interrupt enable bit, T1IE. The timer interrupt enable bit is located in the IEC0 Control register in the interrupt controller.

TABLE 9-1: TIMER1 REGISTER MAP

| SFR Name | Addr. | Bit 15 | Bit 14 | Bit 13 | Bit 12 | Bit 11 | Bit 10 | Bit 9 | Bit 8 | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Reset State |
|----------|-------|-------------------|--------|--------|--------|--------|--------|-------|-------|-------|-------|--------|--------|-------|-------|-------|-------|---------------------|
| TMR1 | 0100 | Timer1 Register | | | | | | | | | | | | | | | | uuuu uuuu uuuu uuuu |
| PR1 | 0102 | Period Register 1 | | | | | | | | | | | | | | | | 1111 1111 1111 1111 |
| T1CON | 0104 | TON | — | TSIDL | — | — | — | — | — | — | TGATE | TCKPS1 | TCKPS0 | — | TSYNC | TCS | — | 0000 0000 0000 0000 |

Legend: u = uninitialized bit; — = unimplemented bit, read as '0'
Note: Refer to the “dsPIC30F Family Reference Manual” (DS70046) for descriptions of register bit fields.

10.0 TIMER2/3 MODULE

Note: This data sheet summarizes features of this group of dsPIC30F devices and is not intended to be a complete reference source. For more information on the CPU, peripherals, register descriptions and general device functionality, refer to the “dsPIC30F Family Reference Manual” (DS70046).

This section describes the 32-bit general purpose Timer module (Timer2/3) and associated Operational modes. Figure 10-1 depicts the simplified block diagram of the 32-bit Timer2/3 module. Figure 10-2 and Figure 10-3 show Timer2/3 configured as two independent 16-bit timers, Timer2 and Timer3, respectively.

The Timer2/3 module is a 32-bit timer (which can be configured as two 16-bit timers) with selectable operating modes. These timers are utilized by other peripheral modules, such as:

- Input Capture
- Output Compare/Simple PWM

The following sections provide a detailed description, including setup and Control registers, along with associated block diagrams for the operational modes of the timers.

The 32-bit timer has the following modes:

- Two independent 16-bit timers (Timer2 and Timer3) with all 16-bit operating modes (except Asynchronous Counter mode)
- Single 32-bit timer operation
- Single 32-bit synchronous counter

Further, the following operational characteristics are supported:

- ADC event trigger
- Timer gate operation
- Selectable prescaler settings
- Timer operation during Idle and Sleep modes
- Interrupt on a 32-bit period register match

These operating modes are determined by setting the appropriate bit(s) in the 16-bit T2CON and T3CON SFRs.

For 32-bit timer/counter operation, Timer2 is the ls word and Timer3 is the ms word of the 32-bit timer.

Note: For 32-bit timer operation, T3CON control bits are ignored. Only T2CON control bits are used for setup and control. Timer2 clock and gate inputs are utilized for the 32-bit timer module, but an interrupt is generated with the Timer3 interrupt flag (T3IF) and the interrupt is enabled with the Timer3 interrupt enable bit (T3IE).

16-bit Timer Mode: In the 16-bit mode, Timer2 and Timer3 can be configured as two independent 16-bit timers. Each timer can be set up in either 16-bit Timer mode or 16-bit Synchronous Counter mode. See Section 9.0 “Timer1 Module” for details on these two operating modes.

The only functional difference between Timer2 and Timer3 is that Timer2 provides synchronization of the clock prescaler output. This is useful for high frequency external clock inputs.

32-bit Timer Mode: In the 32-bit Timer mode, the timer increments on every instruction cycle, up to a match value preloaded into the combined 32-bit Period register PR3/PR2, then resets to ‘0’ and continues to count.

For synchronous 32-bit reads of the Timer2/Timer3 pair, reading the ls word (TMR2 register) causes the ms word to be read and latched into a 16-bit holding register, termed TMR3HLD.

For synchronous 32-bit writes, the holding register (TMR3HLD) must first be written to. When followed by a write to the TMR2 register, the contents of TMR3HLD is transferred and latched into the MSB of the 32-bit timer (TMR3).

32-bit Synchronous Counter Mode: In the 32-bit Synchronous Counter mode, the timer increments on the rising edge of the applied external clock signal which is synchronized with the internal phase clocks. The timer counts up to a match value preloaded in the combined 32-bit period register, PR3/PR2, then resets to ‘0’ and continues.

When the timer is configured for the Synchronous Counter mode of operation and the CPU goes into the Idle mode, the timer stops incrementing unless the TSIDL bit (T2CON<13>) = 0. If TSIDL = 1, the timer module logic resumes the incrementing sequence upon termination of the CPU Idle mode.

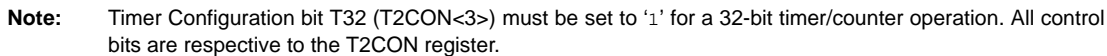


FIGURE 10-2: 16-BIT TIMER2 BLOCK DIAGRAM

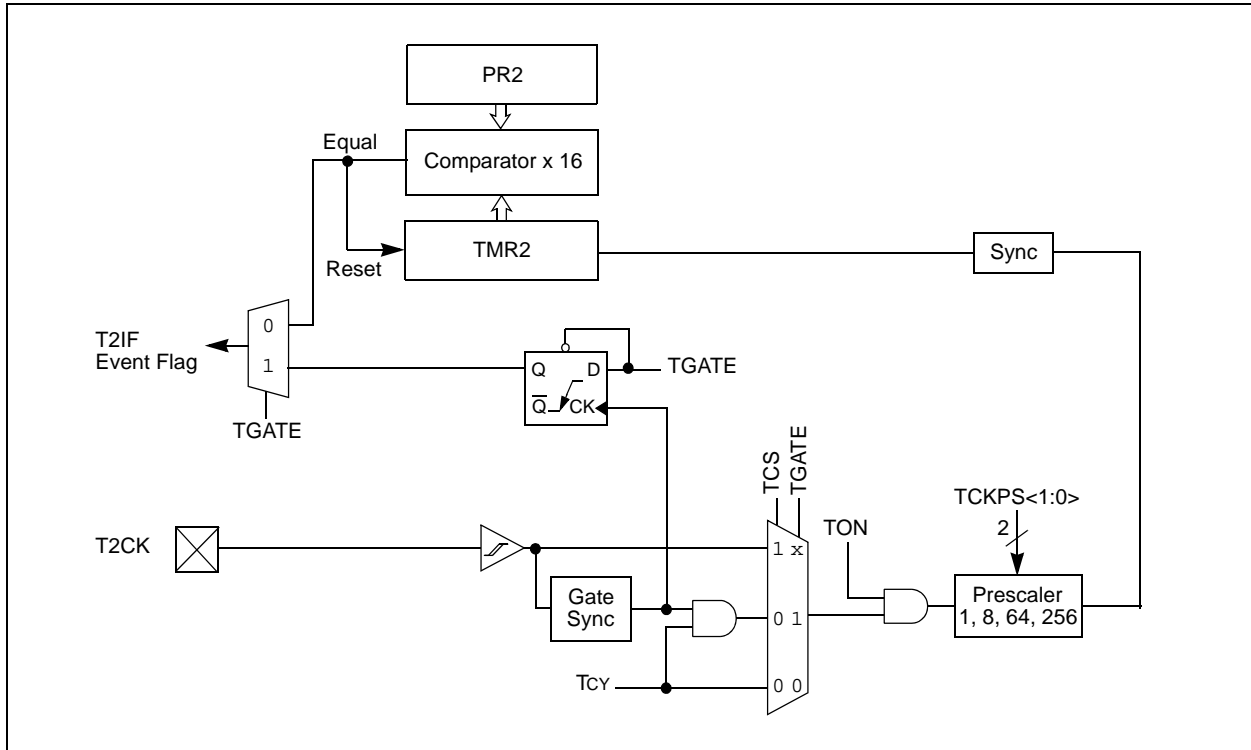
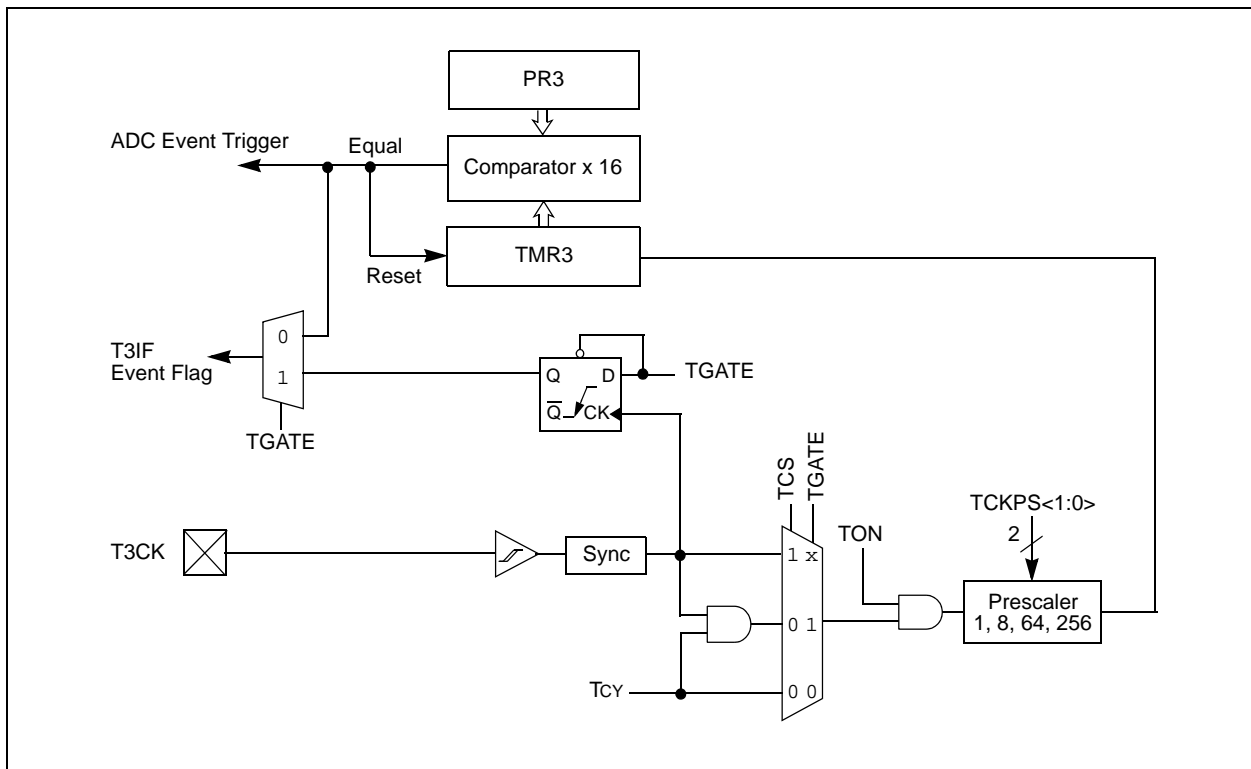


FIGURE 10-3: 16-BIT TIMER3 BLOCK DIAGRAM



10.1 Timer Gate Operation

The 32-bit timer can be placed in the Gated Time Accumulation mode. This mode allows the internal Tcy to increment the respective timer when the gate input signal (T2CK pin) is asserted high. Control bit, TGATE (T2CON<6>), must be set to enable this mode. When in this mode, Timer2 is the originating clock source. The TGATE setting is ignored for Timer3. The timer must be enabled (TON = 1) and the timer clock source set to internal (TCS = 0).

The falling edge of the external signal terminates the count operation but does not reset the timer. The user must reset the timer in order to start counting from zero.

10.2 ADC Event Trigger

When a match occurs between the 32-bit timer (TMR3/TMR2) and the 32-bit combined period register (PR3/PR2), or between the 16-bit timer TMR3 and the 16-bit period register PR3, a special ADC trigger event signal is generated by Timer3.

10.3 Timer Prescaler

The input clock (FOSC/4 or external clock) to the timer has a prescale option of 1:1, 1:8, 1:64, and 1:256, selected by control bits, TCKPS<1:0> (T2CON<5:4> and T3CON<5:4>). For the 32-bit timer operation, the originating clock source is Timer2. The prescaler operation for Timer3 is not applicable in this mode. The prescaler counter is cleared when any of the following occurs:

- A write to the TMR2/TMR3 register
- A write to the T2CON/T3CON register
- A device Reset, such as a POR and BOR

However, if the timer is disabled (TON = 0), the Timer 2 prescaler cannot be reset since the prescaler clock is halted.

TMR2/TMR3 is not cleared when T2CON/T3CON is written.

10.4 Timer Operation During Sleep Mode

The timer does not operate during CPU Sleep mode because the internal clocks are disabled.

10.5 Timer Interrupt

The 32-bit timer module can generate an interrupt-on-period match or on the falling edge of the external gate signal. When the 32-bit timer count matches the respective 32-bit period register, or the falling edge of the external "gate" signal is detected, the T3IF bit (IFS0<7>) is asserted and an interrupt is generated if enabled. In this mode, the T3IF interrupt flag is used as the source of the interrupt. The T3IF bit must be cleared in software.

Enabling an interrupt is accomplished via the respective timer interrupt enable bit, T3IE (IEC0<7>).

TABLE 10-1: TIMER2/3 REGISTER MAP

| SFR Name | Addr. | Bit 15 | Bit 14 | Bit 13 | Bit 12 | Bit 11 | Bit 10 | Bit 9 | Bit 8 | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Reset State |
|----------|-------|--|--------|--------|--------|--------|--------|-------|-------|-------|-------|--------|--------|-------|-------|-------|-------|---------------------|
| TMR2 | 0106 | Timer2 Register | | | | | | | | | | | | | | | | uuuu uuuu uuuu uuuu |
| TMR3HLD | 0108 | Timer3 Holding Register (for 32-bit timer operations only) | | | | | | | | | | | | | | | | uuuu uuuu uuuu uuuu |
| TMR3 | 010A | Timer3 Register | | | | | | | | | | | | | | | | uuuu uuuu uuuu uuuu |
| PR2 | 010C | Period Register 2 | | | | | | | | | | | | | | | | 1111 1111 1111 1111 |
| PR3 | 010E | Period Register 3 | | | | | | | | | | | | | | | | 1111 1111 1111 1111 |
| T2CON | 0110 | TON | — | TSIDL | — | — | — | — | — | — | TGATE | TCKPS1 | TCKPS0 | T32 | — | TCS | — | 0000 0000 0000 0000 |
| T3CON | 0112 | TON | — | TSIDL | — | — | — | — | — | — | TGATE | TCKPS1 | TCKPS0 | — | — | TCS | — | 0000 0000 0000 0000 |

Legend: u = uninitialized bit; — = unimplemented bit, read as '0'

Note: Refer to the "dsPIC30F Family Reference Manual" (DS70046) for descriptions of register bit fields.

NOTES:

11.0 INPUT CAPTURE MODULE

Note: This data sheet summarizes features of this group of dsPIC30F devices and is not intended to be a complete reference source. For more information on the CPU, peripherals, register descriptions and general device functionality, refer to the “dsPIC30F Family Reference Manual” (DS70046).

This section describes the input capture module and associated operational modes. The features provided by this module are useful in applications requiring frequency (period) and pulse measurement.

Figure 11-1 depicts a block diagram of the input capture module. Input capture is useful for such modes as:

- Frequency/Period/Pulse Measurements
- Additional Sources of External Interrupts

Important operational features of the input capture module are:

- Simple Capture Event mode
- Timer2 and Timer3 mode selection
- Interrupt on input capture event

These operating modes are determined by setting the appropriate bits in the IC1CON and IC2CON registers. The dsPIC30F2011/2012/3012/3013 devices have two capture channels.

11.1 Simple Capture Event Mode

The simple capture events in the dsPIC30F product family are:

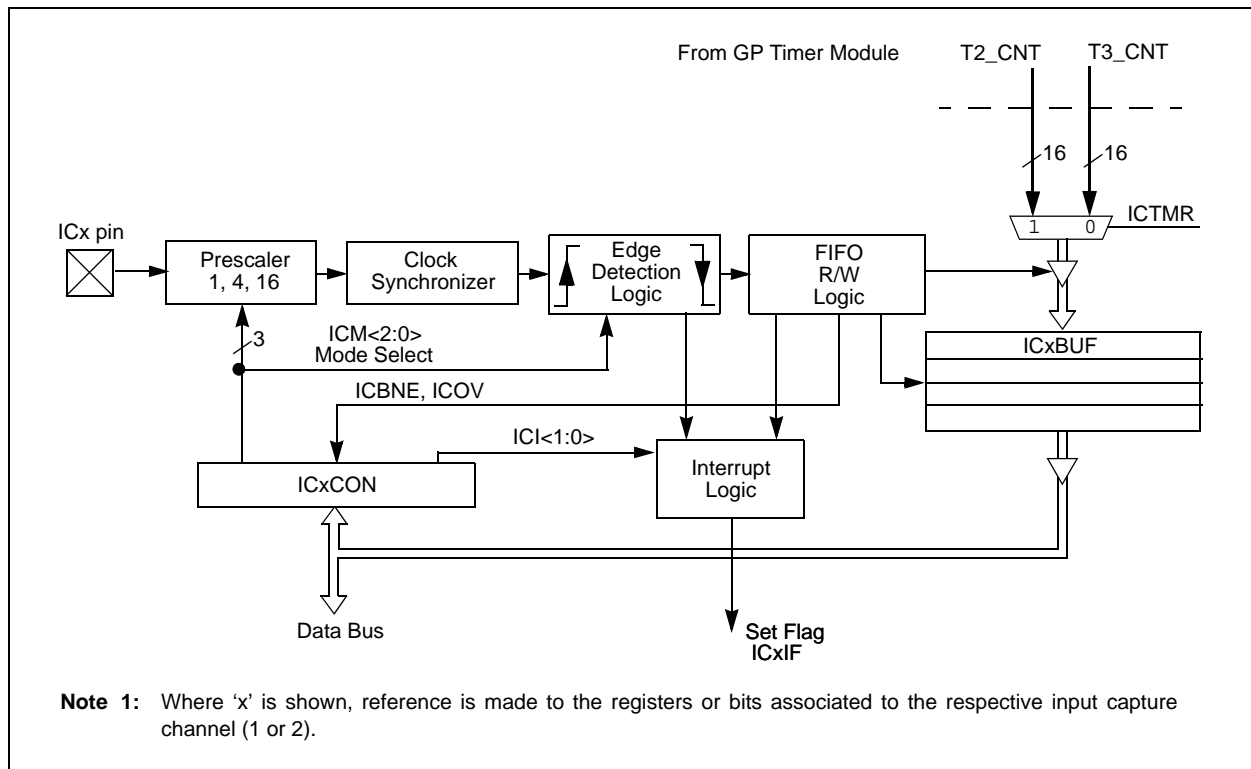
- Capture every falling edge
- Capture every rising edge
- Capture every 4th rising edge
- Capture every 16th rising edge
- Capture every rising and falling edge

These simple Input Capture modes are configured by setting the appropriate bits, ICM<2:0> (ICxCON<2:0>).

11.1.1 CAPTURE PRESCALER

There are four input capture prescaler settings specified by bits ICM<2:0> (ICxCON<2:0>). Whenever the capture channel is turned off, the prescaler counter is cleared. In addition, any Reset clears the prescaler counter.

FIGURE 11-1: INPUT CAPTURE MODE BLOCK DIAGRAM⁽¹⁾



11.1.2 CAPTURE BUFFER OPERATION

Each capture channel has an associated FIFO buffer which is four 16-bit words deep. There are two status flags which provide status on the FIFO buffer:

- ICBNE – Input Capture Buffer Not Empty
- ICOV – Input Capture Overflow

The ICBNE is set on the first input capture event and remains set until all capture events have been read from the FIFO. As each word is read from the FIFO, the remaining words are advanced by one position within the buffer.

In the event that the FIFO is full with four capture events, and a fifth capture event occurs prior to a read of the FIFO, an overflow condition occurs and the ICOV bit is set to a logic '1'. The fifth capture event is lost and is not stored in the FIFO. No additional events are captured until all four events have been read from the buffer.

If a FIFO read is performed after the last read and no new capture event has been received, the read will yield indeterminate results.

11.1.3 TIMER2 AND TIMER3 SELECTION MODE

The input capture module consists of up to 8 input capture channels. Each channel can select between one of two timers for the time base, Timer2 or Timer3.

Selection of the timer resource is accomplished through SFR bit, ICTMR (ICxCON<7>). Timer3 is the default timer resource available for the input capture module.

11.1.4 HALL SENSOR MODE

When the input capture module is set for capture on every edge, rising and falling, ICM<2:0> = 001, the following operations are performed by the input capture logic:

- The input capture interrupt flag is set on every edge, rising and falling.
- The interrupt on Capture mode setting bits, ICI<1:0>, is ignored since every capture generates an interrupt.
- A capture overflow condition is not generated in this mode.

11.2 Input Capture Operation During Sleep and Idle Modes

An input capture event generates a device wake-up or interrupt, if enabled, if the device is in CPU Idle or Sleep mode.

Independent of the timer being enabled, the input capture module wakes up from the CPU Sleep or Idle mode when a capture event occurs if ICM<2:0> = 111 and the interrupt enable bit is asserted. The same wake-up can generate an interrupt if the conditions for processing the interrupt have been satisfied. The wake-up feature is useful as a method of adding extra external pin interrupts.

11.2.1 INPUT CAPTURE IN CPU SLEEP MODE

CPU Sleep mode allows input capture module operation with reduced functionality. In the CPU Sleep mode, the ICI<1:0> bits are not applicable and the input capture module can only function as an external interrupt source.

The capture module must be configured for interrupt only on rising edge (ICM<2:0> = 111) in order for the input capture module to be used while the device is in Sleep mode. The prescale settings of 4:1 or 16:1 are not applicable in this mode.

11.2.2 INPUT CAPTURE IN CPU IDLE MODE

CPU Idle mode allows input capture module operation with full functionality. In the CPU Idle mode, the Interrupt mode selected by the ICI<1:0> bits is applicable, as well as the 4:1 and 16:1 capture prescale settings which are defined by control bits ICM<2:0>. This mode requires the selected timer to be enabled. Moreover, the ICSIDL bit must be asserted to a logic '0'.

If the input capture module is defined as ICM<2:0> = 111 in CPU Idle mode, the input capture pin serves only as an external interrupt pin.

11.3 Input Capture Interrupts

The input capture channels have the ability to generate an interrupt based on the selected number of capture events. The selection number is set by control bits, ICI<1:0> (ICxCON<6:5>).

Each channel provides an interrupt flag (ICxIF) bit. The respective capture channel interrupt flag is located in the corresponding IFSx register.

Enabling an interrupt is accomplished via the respective capture channel interrupt enable (ICxIE) bit. The capture interrupt enable bit is located in the corresponding IEC Control register.

TABLE 11-1: INPUT CAPTURE REGISTER MAP

| SFR Name | Addr. | Bit 15 | Bit 14 | Bit 13 | Bit 12 | Bit 11 | Bit 10 | Bit 9 | Bit 8 | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Reset State |
|----------|-------|--------------------------|--------|--------|--------|--------|--------|-------|-------|-------|----------|-------|-------|----------|-------|-------|---------------------|---------------------|
| IC1BUF | 0140 | Input 1 Capture Register | | | | | | | | | | | | | | | | uuuu uuuu uuuu uuuu |
| IC1CON | 0142 | — | — | ICSIDL | — | — | — | — | — | ICTMR | ICI<1:0> | ICOV | ICBNE | ICM<2:0> | | | 0000 0000 0000 0000 | |
| IC2BUF | 0144 | Input 2 Capture Register | | | | | | | | | | | | | | | | uuuu uuuu uuuu uuuu |
| IC2CON | 0146 | — | — | ICSIDL | — | — | — | — | — | ICTMR | ICI<1:0> | ICOV | ICBNE | ICM<2:0> | | | 0000 0000 0000 0000 | |

Legend: u = uninitialized bit; — = unimplemented bit, read as '0'
Note: Refer to the “dsPIC30F Family Reference Manual” (DS70046) for descriptions of register bit fields.

NOTES:

12.0 OUTPUT COMPARE MODULE

Note: This data sheet summarizes features of this group of dsPIC30F devices and is not intended to be a complete reference source. For more information on the CPU, peripherals, register descriptions and general device functionality, refer to the “dsPIC30F Family Reference Manual” (DS70046).

This section describes the output compare module and associated operational modes. The features provided by this module are useful in applications requiring operational modes, such as:

- Generation of Variable Width Output Pulses
- Power Factor Correction

Figure 12-1 depicts a block diagram of the output compare module.

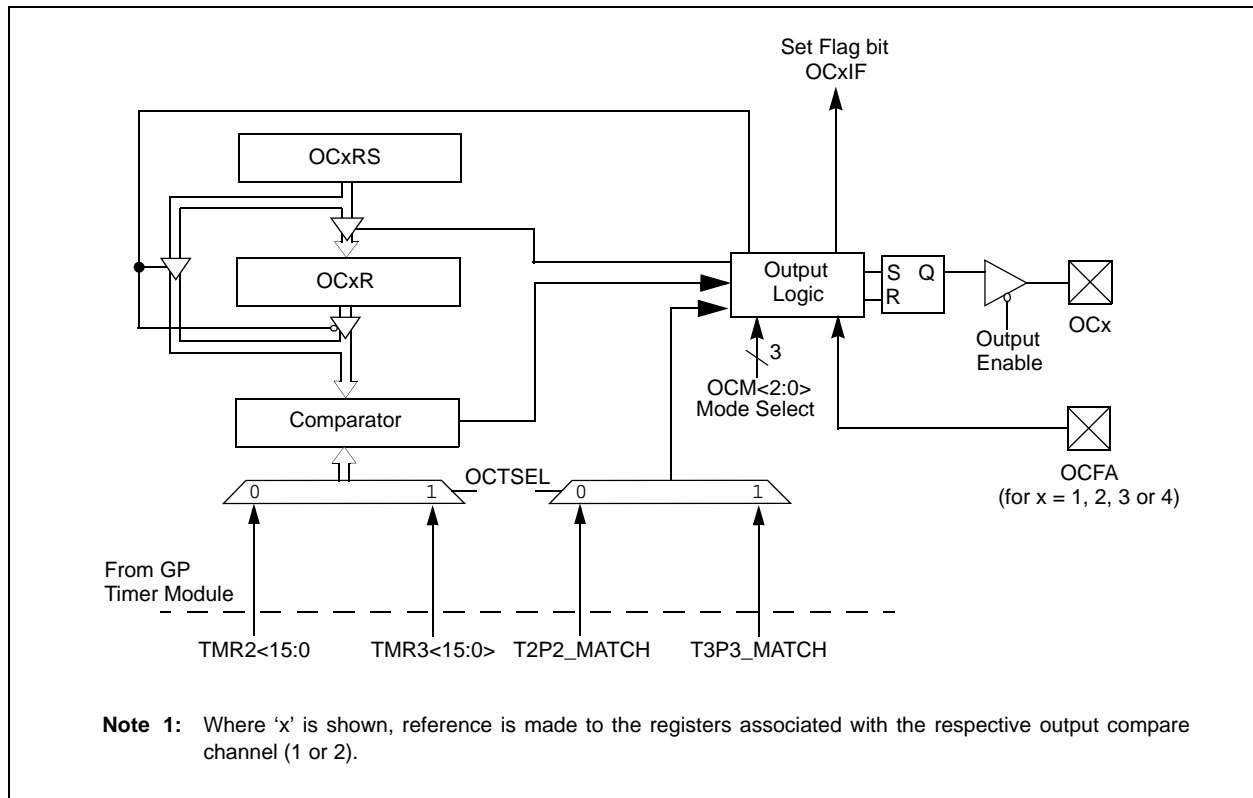
The key operational features of the output compare module include:

- Timer2 and Timer3 Selection mode
- Simple Output Compare Match mode
- Dual Output Compare Match mode
- Simple PWM mode
- Output Compare During Sleep and Idle modes
- Interrupt on Output Compare/PWM Event

These operating modes are determined by setting the appropriate bits in the 16-bit OC1CON and OC2CON registers. The dsPIC30F2011/2012/3012/3013 devices have 2 compare channels.

OCxRS and OCxR in Figure 12-1 represent the Dual Compare registers. In the Dual Compare mode, the OCxR register is used for the first compare and OCxRS is used for the second compare.

FIGURE 12-1: OUTPUT COMPARE MODE BLOCK DIAGRAM⁽¹⁾



12.1 Timer2 and Timer3 Selection Mode

Each output compare channel can select between one of two 16-bit timers, Timer2 or Timer3.

The selection of the timers is controlled by the OCTSEL bit (OCxCON<3>). Timer2 is the default timer resource for the output compare module.

12.2 Simple Output Compare Match Mode

When control bits OCM<2:0> (OCxCON<2:0>) = 001, 010 or 011, the selected output compare channel is configured for one of three simple Output Compare Match modes:

- Compare forces I/O pin low
- Compare forces I/O pin high
- Compare toggles I/O pin

The OCxR register is used in these modes. The OCxR register is loaded with a value and is compared to the selected incrementing timer count. When a compare occurs, one of these Compare Match modes occurs. If the counter resets to zero before reaching the value in OCxR, the state of the OCx pin remains unchanged.

12.3 Dual Output Compare Match Mode

When control bits OCM<2:0> (OCxCON<2:0>) = 100 or 101, the selected output compare channel is configured for one of two Dual Output Compare modes, which are:

- Single Output Pulse mode
- Continuous Output Pulse mode

12.3.1 SINGLE PULSE MODE

For the user to configure the module for the generation of a single output pulse, the following steps are required (assuming timer is off):

- Determine instruction cycle time Tcy.
- Calculate desired pulse width value based on Tcy.
- Calculate time to start pulse from timer start value of 0x0000.
- Write pulse width start and stop times into OCxR and OCxRS Compare registers (x denotes channel 1 to N).
- Set Timer Period register to value equal to or greater than value in OCxRS Compare register.
- Set OCM<2:0> = 100.
- Enable timer, TON bit (TxCON<15>) = 1.

To initiate another single pulse, issue another write to set OCM<2:0> = 100.

12.3.2 CONTINUOUS PULSE MODE

For the user to configure the module for the generation of a continuous stream of output pulses, the following steps are required:

- Determine instruction cycle time Tcy.
- Calculate desired pulse value based on Tcy.
- Calculate timer to start pulse width from timer start value of 0x0000.
- Write pulse width start and stop times into OCxR and OCxRS (x denotes channel 1 to N) Compare registers, respectively.
- Set Timer Period register to value equal to or greater than value in OCxRS Compare register.
- Set OCM<2:0> = 101.
- Enable timer, TON bit (TxCON<15>) = 1.

12.4 Simple PWM Mode

When control bits OCM<2:0> (OCxCON<2:0>) = 110 or 111, the selected output compare channel is configured for the PWM mode of operation. When configured for the PWM mode of operation, OCxR is the main latch (read-only) and OCxRS is the secondary latch. This enables glitchless PWM transitions.

The user must perform the following steps in order to configure the output compare module for PWM operation:

1. Set the PWM period by writing to the appropriate period register.
2. Set the PWM duty cycle by writing to the OCxRS register.
3. Configure the output compare module for PWM operation.
4. Set the TMRx prescale value and enable the Timer, TON bit (TxCON<15>) = 1.

12.4.1 INPUT PIN FAULT PROTECTION FOR PWM

When control bits OCM<2:0> (OCxCON<2:0>) = 111, the selected output compare channel is again configured for the PWM mode of operation with the additional feature of input Fault protection. While in this mode, if a logic '0' is detected on the OCFA/B pin, the respective PWM output pin is placed in the high impedance input state. The OCFLT bit (OCxCON<4>) indicates whether a Fault condition has occurred. This state is maintained until both of the following events have occurred:

- The external Fault condition has been removed.
- The PWM mode has been re-enabled by writing to the appropriate control bits.

12.4.2 PWM PERIOD

The PWM period is specified by writing to the PRx register. The PWM period can be calculated using [Equation 12-1](#).

EQUATION 12-1:

$$PWM\ period = [(PRx) + 1] \cdot 4 \cdot T_{osc} \cdot (TMRx\ prescale\ value)$$

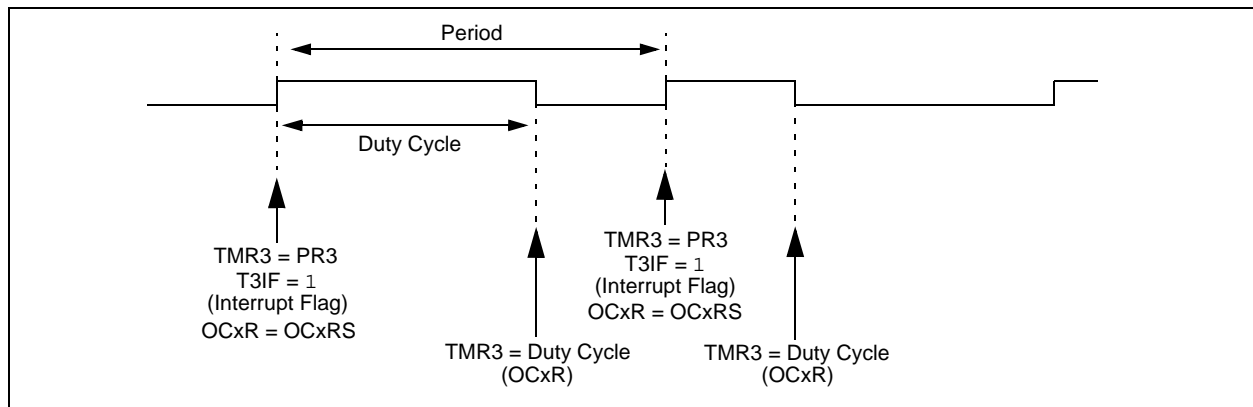
PWM frequency is defined as $1/[PWM\ period]$.

When the selected TMRx is equal to its respective period register, PRx, the following four events occur on the next increment cycle:

- TMRx is cleared.
- The OCx pin is set.
 - Exception 1: If PWM duty cycle is 0x0000, the OCx pin remains low.
 - Exception 2: If duty cycle is greater than PRx, the pin remains high.
- The PWM duty cycle is latched from OCxRS into OCxR.
- The corresponding timer interrupt flag is set.

See [Figure 12-2](#) for key PWM period comparisons. Timer3 is referred to in [Figure 12-2](#) for clarity.

FIGURE 12-2: PWM OUTPUT TIMING



12.5 Output Compare Operation During CPU Sleep Mode

When the CPU enters Sleep mode, all internal clocks are stopped. Therefore, when the CPU enters the Sleep state, the output compare channel drives the pin to the active state that was observed prior to entering the CPU Sleep state.

For example, if the pin was high when the CPU entered the Sleep state, the pin remains high. Likewise, if the pin was low when the CPU entered the Sleep state, the pin remains low. In either case, the output compare module resumes operation when the device wakes up.

12.6 Output Compare Operation During CPU Idle Mode

When the CPU enters the Idle mode, the output compare module can operate with full functionality.

The output compare channel operates during the CPU Idle mode if the OCSIDL bit (OCxCON<13>) is at logic '0' and the selected time base (Timer2 or Timer3) is enabled and the TSIDL bit of the selected timer is set to logic '0'.

12.7 Output Compare Interrupts

The output compare channels have the ability to generate an interrupt on a compare match, for whichever Match mode has been selected.

For all modes except the PWM mode, when a compare event occurs, the respective interrupt flag (OCxIF) is asserted and an interrupt is generated if enabled. The OCxIF bit is located in the corresponding IFS register and must be cleared in software. The interrupt is enabled via the respective compare interrupt enable (OCxIE) bit located in the corresponding IEC Control register.

For the PWM mode, when an event occurs, the respective timer interrupt flag (T2IF or T3IF) is asserted and an interrupt is generated if enabled. The IF bit is located in the IFS0 register and must be cleared in software. The interrupt is enabled via the respective timer interrupt enable bit (T2IE or T3IE) located in the IEC0 Control register. The output compare interrupt flag is never set during the PWM mode of operation.

TABLE 12-1: OUTPUT COMPARE REGISTER MAP

| SFR Name | Addr. | Bit 15 | Bit 14 | Bit 13 | Bit 12 | Bit 11 | Bit 10 | Bit 9 | Bit 8 | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Reset State |
|----------|-------|-------------------------------------|--------|--------|--------|--------|--------|-------|-------|-------|-------|-------|-------|--------|----------|-------|-------|---------------------|
| OC1RS | 0180 | Output Compare 1 Secondary Register | | | | | | | | | | | | | | | | 0000 0000 0000 0000 |
| OC1R | 0182 | Output Compare 1 Main Register | | | | | | | | | | | | | | | | 0000 0000 0000 0000 |
| OC1CON | 0184 | — | — | OCSIDL | — | — | — | — | — | — | — | — | OCFLT | OCTSEL | OCM<2:0> | | | 0000 0000 0000 0000 |
| OC2RS | 0186 | Output Compare 2 Secondary Register | | | | | | | | | | | | | | | | 0000 0000 0000 0000 |
| OC2R | 0188 | Output Compare 2 Main Register | | | | | | | | | | | | | | | | 0000 0000 0000 0000 |
| OC2CON | 018A | — | — | OCSIDL | — | — | — | — | — | — | — | — | OCFLT | OCTSEL | OCM<2:0> | | | 0000 0000 0000 0000 |

Legend: — = unimplemented bit, read as '0'

Note: Refer to the "dsPIC30F Family Reference Manual" (DS70046) for descriptions of register bit fields.

NOTES:

13.0 SPI™ MODULE

Note: This data sheet summarizes features of this group of dsPIC30F devices and is not intended to be a complete reference source. For more information on the CPU, peripherals, register descriptions and general device functionality, refer to the “dsPIC30F Family Reference Manual” (DS70046).

The Serial Peripheral Interface (SPI™) module is a synchronous serial interface. It is useful for communicating with other peripheral devices, such as EEPROMs, shift registers, display drivers and A/D converters, or other microcontrollers. It is compatible with Motorola's SPI and SIOP interfaces. The dsPIC30F2011/2012/3012/3013 devices feature one SPI module, SPI1.

13.1 Operating Function Description

Figure 13-1 is a simplified block diagram of the SPI module, which consists of a 16-bit shift register, SPI1SR, used for shifting data in and out, and a buffer register, SPI1BUF. Control register SPI1CON (not shown) configures the module. Additionally, status register SPI1STAT (not shown) indicates various status conditions.

Note: See “dsPIC30F Family Reference Manual” (DS70046) for detailed information on the control and status registers.

Four I/O pins comprise the serial interface:

- SDI1 (serial data input)
- SDO1 (serial data output)
- SCK1 (shift clock input or output)
- SS1 (active-low slave select).

In Master mode operation, SCK1 is a clock output. In Slave mode, it is a clock input.

A series of eight (8) or sixteen (16) clock pulses shift out bits from the SPI1SR to SDO1 pin and simultaneously shift in data from SDI1 pin. An interrupt is generated when the transfer is complete and the interrupt flag bit (SPI1IF) is set. This interrupt can be disabled through the interrupt enable bit, SPI1IE.

The receive operation is double-buffered. When a complete byte is received, it is transferred from SPI1SR to SPI1BUF.

If the receive buffer is full when new data is being transferred from SPI1SR to SPI1BUF, the module will set the SPIROV bit indicating an overflow condition. The transfer of the data from SPI1SR to SPI1BUF is not completed and the new data is lost. The module will not respond to SCL transitions while SPIROV is '1', effectively disabling the module until SPI1BUF is read by user software.

Transmit writes are also double-buffered. The user writes to SPI1BUF. When the master or slave transfer is completed, the contents of the shift register (SPI1SR) are moved to the receive buffer. If any transmit data has been written to the buffer register, the contents of the transmit buffer are moved to SPI1SR. The received data is thus placed in SPI1BUF and the transmit data in SPI1SR is ready for the next transfer.

Note: Both the transmit buffer (SPI1TXB) and the receive buffer (SPI1RXB) are mapped to the same register address, SPI1BUF.

FIGURE 13-1: SPI BLOCK DIAGRAM

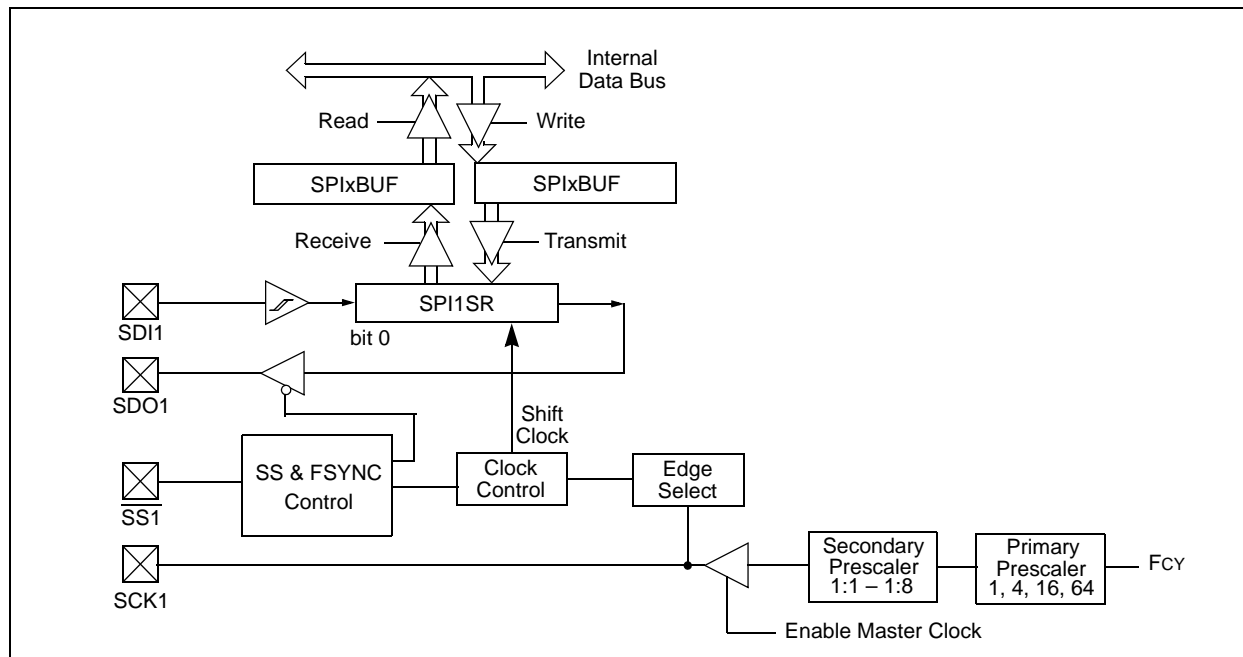


Figure 13-2 depicts the a master/slave connection between two processors. In Master mode, the clock is generated by prescaling the system clock. Data is transmitted as soon as a value is written to SPI1BUF. The interrupt is generated at the middle of the transfer of the last bit.

In Slave mode, data is transmitted and received as external clock pulses appear on SCK. Again, the interrupt is generated when the last bit is latched. If $\overline{SS1}$ control is enabled, then transmission and reception are enabled only when $\overline{SS1}$ = low. The SDO1 output will be disabled in $\overline{SS1}$ mode with $\overline{SS1}$ high.

The clock provided to the module is ($F_{osc}/4$). This clock is then prescaled by the primary ($PPRE<1:0>$) and the secondary ($SPRE<2:0>$) prescale factors. The CKE bit determines whether transmit occurs on transition from active clock state to Idle clock state, or vice versa. The CKP bit selects the Idle state (high or low) for the clock.

13.1.1 WORD AND BYTE COMMUNICATION

A control bit, MODE16 ($SPI1CON<10>$), allows the module to communicate in either 16-bit or 8-bit mode. 16-bit operation is identical to 8-bit operation except that the number of bits transmitted is 16 instead of 8.

The user software must disable the module prior to changing the MODE16 bit. The SPI module is reset when the MODE16 bit is changed by the user.

A basic difference between 8-bit and 16-bit operation is that the data is transmitted out of bit 7 of the SPI1SR for 8-bit operation, and data is transmitted out of bit 15 of the SPI1SR for 16-bit operation. In both modes, data is shifted into bit 0 of the SPI1SR.

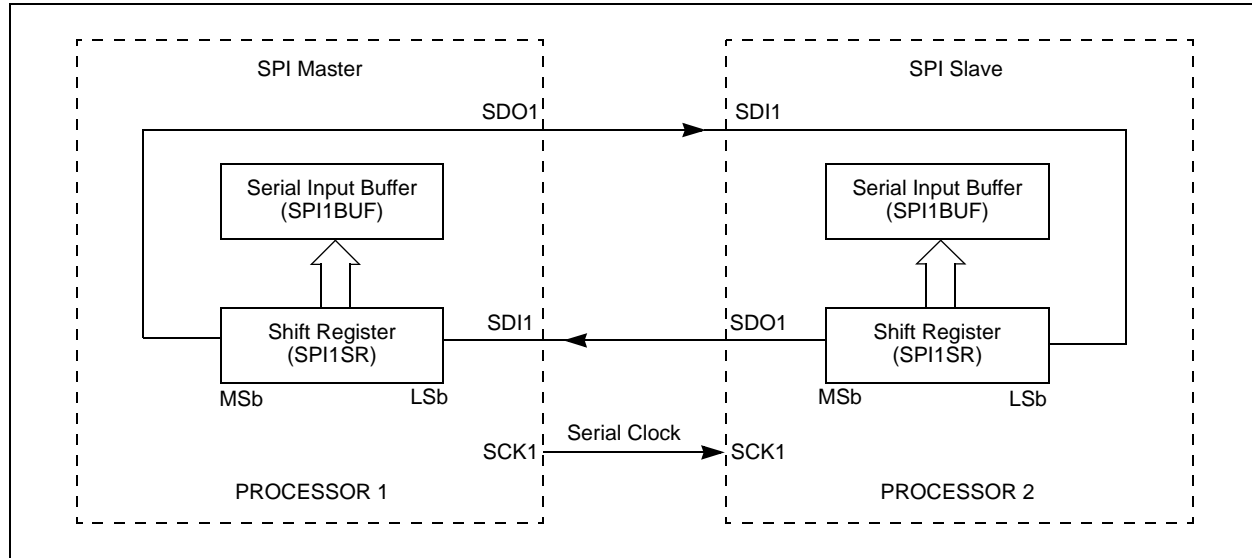
13.1.2 SDO1 DISABLE

A control bit, DISSDO, is provided to the SPI1CON register to allow the SDO1 output to be disabled. This will allow the SPI module to be connected in an input only configuration. SDO1 can also be used for general purpose I/O.

13.2 Framed SPI Support

The module supports a basic framed SPI protocol in Master or Slave mode. The control bit, \overline{FRMEN} , enables framed SPI support and causes the $\overline{SS1}$ pin to perform the Frame Synchronization Pulse (FSYNC) function. The control bit, SPIFSD, determines whether the $\overline{SS1}$ pin is an input or an output (i.e., whether the module receives or generates the Frame Synchronization Pulse). The frame pulse is an active-high pulse for a single SPI clock cycle. When Frame Synchronization is enabled, the data transmission starts only on the subsequent transmit edge of the SPI clock.

FIGURE 13-2: SPI MASTER/SLAVE CONNECTION



13.3 Slave Select Synchronization

The $\overline{SS1}$ pin allows a Synchronous Slave mode. The SPI must be configured in SPI Slave mode with $\overline{SS1}$ pin control enabled ($SSEN = 1$). When the $\overline{SS1}$ pin is low, transmission and reception are enabled and the SDOx pin is driven. When $\overline{SS1}$ pin goes high, the SDOx pin is no longer driven. Also, the SPI module is resynchronized, and all counters/control circuitry are reset. Therefore, when the $\overline{SS1}$ pin is asserted low again, transmission/reception will begin at the MSb even if $\overline{SS1}$ had been de-asserted in the middle of a transmit/receive.

13.4 SPI Operation During CPU Sleep Mode

During Sleep mode, the SPI module is shut down. If the CPU enters Sleep mode while an SPI transaction is in progress, then the transmission and reception is aborted.

The transmitter and receiver will stop in Sleep mode. However, register contents are not affected by entering or exiting Sleep mode.

13.5 SPI Operation During CPU Idle Mode

When the device enters Idle mode, all clock sources remain functional. The SPISIDL bit ($SPI1STAT<13>$) selects if the SPI module will stop or continue on idle. If $SPISIDL = 0$, the module will continue to operate when the CPU enters Idle mode. If $SPISIDL = 1$, the module will stop when the CPU enters Idle mode.

TABLE 13-1: SPI1 REGISTER MAP

| SFR Name | Addr. | Bit 15 | Bit 14 | Bit 13 | Bit 12 | Bit 11 | Bit 10 | Bit 9 | Bit 8 | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Reset State |
|----------|-------|-----------------------------|--------|---------|--------|--------|--------|-------|-------|-------|--------|-------|-------|-------|-------|--------|--------|---------------------|
| SPI1STAT | 0220 | SPIEN | — | SPISIDL | — | — | — | — | — | — | SPIROV | — | — | — | — | SPITBF | SPIRBF | 0000 0000 0000 0000 |
| SPI1CON | 0222 | — | FRMEN | SPIFSD | — | DISSDO | MODE16 | SMP | CKE | SSEN | CKP | MSTEN | SPRE2 | SPRE1 | SPRE0 | PPRE1 | PPRE0 | 0000 0000 0000 0000 |
| SPI1BUF | 0224 | Transmit and Receive Buffer | | | | | | | | | | | | | | | | 0000 0000 0000 0000 |

Legend: — = unimplemented bit, read as '0'

Note: Refer to the “dsPIC30F Family Reference Manual” (DS70046) for descriptions of register bit fields.

14.0 I²C™ MODULE

Note: This data sheet summarizes features of this group of dsPIC30F devices and is not intended to be a complete reference source. For more information on the CPU, peripherals, register descriptions and general device functionality, refer to the “dsPIC30F Family Reference Manual” (DS70046).

The Inter-Integrated Circuit (I²C™) module provides complete hardware support for both Slave and Multi-Master modes of the I²C serial communication standard, with a 16-bit interface.

This module offers the following key features:

- I²C interface supporting both master and slave operation.
- I²C Slave mode supports 7-bit and 10-bit addressing.
- I²C Master mode supports 7-bit and 10-bit addressing.
- I²C port allows bidirectional transfers between master and slaves.
- Serial clock synchronization for I²C port can be used as a handshake mechanism to suspend and resume serial transfer (SCLREL control).
- I²C supports multi-master operation; detects bus collision and will arbitrate accordingly.

14.1 Operating Function Description

The hardware fully implements all the master and slave functions of the I²C Standard and Fast mode specifications, as well as 7 and 10-bit addressing.

Thus, the I²C module can operate either as a slave or a master on an I²C bus.

14.1.1 VARIOUS I²C MODES

The following types of I²C operation are supported:

- I²C slave operation with 7-bit addressing
- I²C slave operation with 10-bit addressing
- I²C master operation with 7-bit or 10-bit addressing

See the I²C programmer's model (Figure 14-1).

14.1.2 PIN CONFIGURATION IN I²C MODE

I²C has a 2-pin interface; the SCL pin is clock and the SDA pin is data.

14.1.3 I²C REGISTERS

I2CCON and I2CSTAT are control and status registers, respectively. The I2CCON register is readable and writable. The lower 6 bits of I2CSTAT are read-only. The remaining bits of the I2CSTAT are read/write.

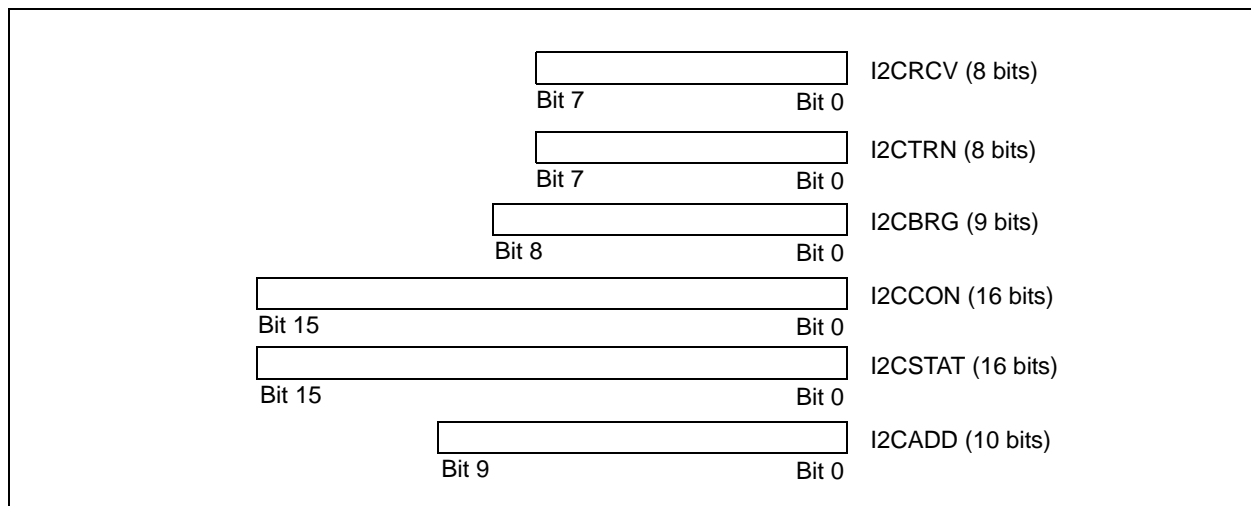
I2CRSR is the shift register used for shifting data, whereas I2CRCV is the buffer register to which data bytes are written, or from which data bytes are read. I2CRCV is the receive buffer as shown in Figure 14-1. I2CTRN is the transmit register to which bytes are written during a transmit operation, as shown in Figure 14-2.

The I2CADD register holds the slave address. A Status bit, ADD10, indicates 10-bit Address mode. The I2CBRG acts as the Baud Rate Generator reload value.

In receive operations, I2CRSR and I2CRCV together form a double-buffered receiver. When I2CRSR receives a complete byte, it is transferred to I2CRCV and an interrupt pulse is generated. During transmission, the I2CTRN is not double-buffered.

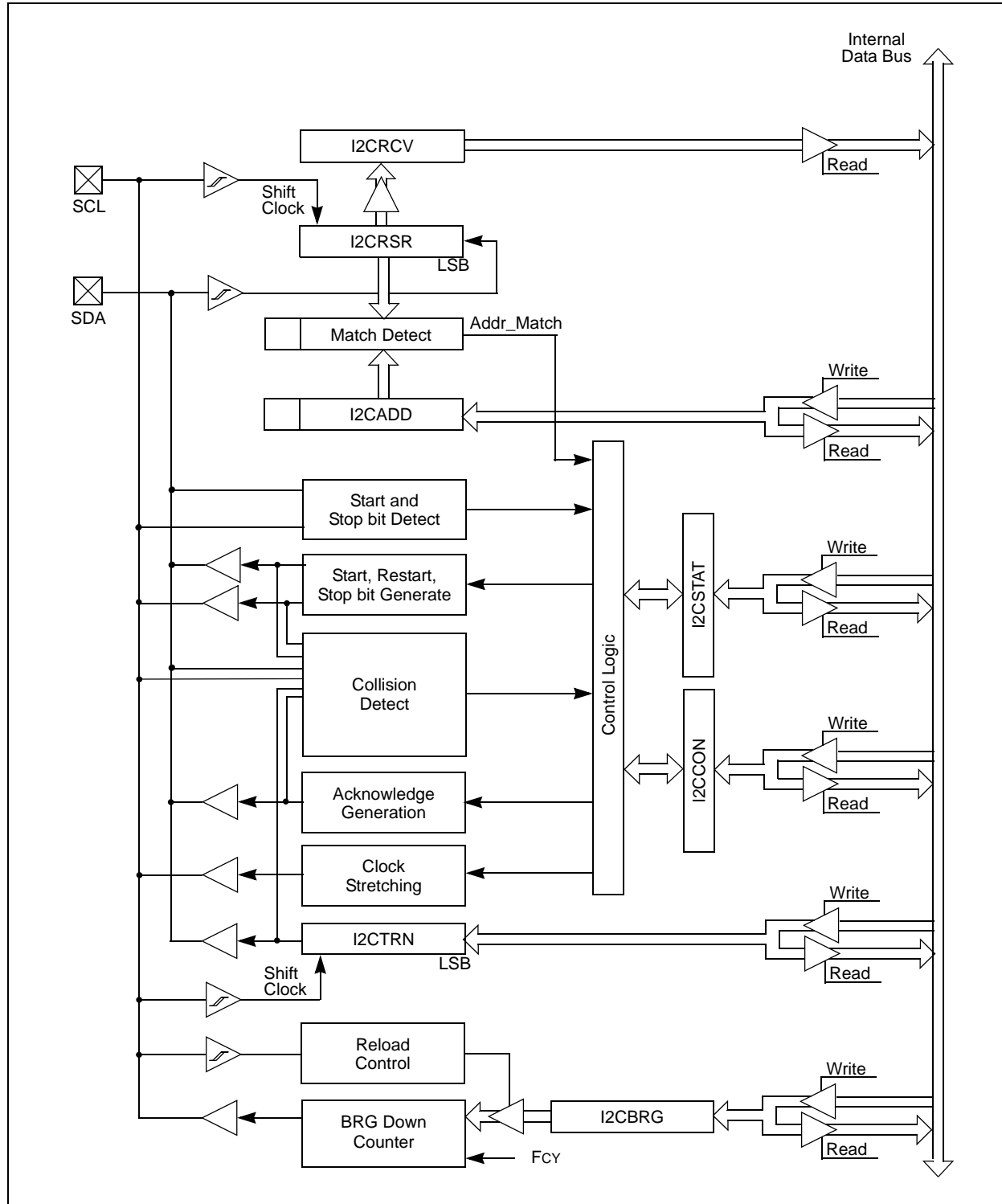
Note: Following a Restart condition in 10-bit mode, the user only needs to match the first 7-bit address.

FIGURE 14-1: PROGRAMMER'S MODEL



dsPIC30F2011/2012/3012/3013

FIGURE 14-2: I²C™ BLOCK DIAGRAM



14.2 I²C Module Addresses

The I2CADD register contains the Slave mode addresses. The register is a 10-bit register.

If the A10M bit (I2CCON<10>) is '0', the address is interpreted by the module as a 7-bit address. When an address is received, it is compared to the 7 LSb of the I2CADD register.

If the A10M bit is '1', the address is assumed to be a 10-bit address. When an address is received, it will be compared with the binary value '11110 A9 A8' (where A9 and A8 are two Most Significant bits of I2CADD). If that value matches, the next address will be compared with the Least Significant 8 bits of I2CADD, as specified in the 10-bit addressing protocol.

The 7-bit I²C Slave Addresses supported by the dsPIC30F are shown in Table 14-1.

TABLE 14-1: 7-BIT I²C™ SLAVE ADDRESSES

| | |
|-----------|---------------------------------------|
| 0x00 | General call address or start byte |
| 0x01-0x03 | Reserved |
| 0x04-0x07 | Hs-mode Master codes |
| 0x04-0x77 | Valid 7-bit addresses |
| 0x78-0x7b | Valid 10-bit addresses (lower 7 bits) |
| 0x7c-0x7f | Reserved |

14.3 I²C 7-bit Slave Mode Operation

Once enabled (I2CEN = 1), the slave module will wait for a Start bit to occur (i.e., the I²C module is 'Idle'). Following the detection of a Start bit, 8 bits are shifted into I2CRSR and the address is compared against I2CADD. In 7-bit mode (A10M = 0), bits I2CADD<6:0> are compared against I2CRSR<7:1> and I2CRSR<0> is the R_W bit. All incoming bits are sampled on the rising edge of SCL.

If an address match occurs, an acknowledgement will be sent, and the slave event interrupt flag (SI2CIF) is set on the falling edge of the ninth (ACK) bit. The address match does not affect the contents of the I2CRCV buffer or the RBF bit.

14.3.1 SLAVE TRANSMISSION

If the R_W bit received is a '1', then the serial port will go into Transmit mode. It will send ACK on the ninth bit and then hold SCL to '0' until the CPU responds by writing to I2CTRNL. SCL is released by setting the SCLREL bit, and 8 bits of data are shifted out. Data bits are shifted out on the falling edge of SCL, such that SDA is valid during SCL high. The interrupt pulse is sent on the falling edge of the ninth clock pulse, regardless of the status of the ACK received from the master.

14.3.2 SLAVE RECEPTION

If the R_W bit received is a '0' during an address match, then Receive mode is initiated. Incoming bits are sampled on the rising edge of SCL. After 8 bits are received, if I2CRCV is not full or I2COV is not set, I2CRSR is transferred to I2CRCV. ACK is sent on the ninth clock.

If the RBF flag is set, indicating that I2CRCV is still holding data from a previous operation (RBF = 1), then ACK is not sent; however, the interrupt pulse is generated. In the case of an overflow, the contents of the I2CRSR are not loaded into the I2CRCV.

Note: The I2CRCV will be loaded if the I2COV bit = 1 and the RBF flag = 0. In this case, a read of the I2CRCV was performed but the user did not clear the state of the I2COV bit before the next receive occurred. The acknowledgement is not sent (ACK = 1) and the I2CRCV is updated.

14.4 I²C 10-bit Slave Mode Operation

In 10-bit mode, the basic receive and transmit operations are the same as in the 7-bit mode. However, the criteria for address match is more complex.

The I²C specification dictates that a slave must be addressed for a write operation with two address bytes following a Start bit.

The A10M bit is a control bit that signifies that the address in I2CADD is a 10-bit address rather than a 7-bit address. The address detection protocol for the first byte of a message address is identical for 7-bit and 10-bit messages, but the bits being compared are different.

I2CADD holds the entire 10-bit address. Upon receiving an address following a Start bit, I2CRSR <7:3> is compared against a literal '11110' (the default 10-bit address) and I2CRSR<2:1> are compared against I2CADD<9:8>. If a match occurs and if R_W = 0, the interrupt pulse is sent. The ADD10 bit will be cleared to indicate a partial address match. If a match fails or R_W = 1, the ADD10 bit is cleared and the module returns to the Idle state.

The low byte of the address is then received and compared with I2CADD<7:0>. If an address match occurs, the interrupt pulse is generated and the ADD10 bit is set, indicating a complete 10-bit address match. If an address match did not occur, the ADD10 bit is cleared and the module returns to the Idle state.

14.4.1 10-BIT MODE SLAVE TRANSMISSION

Once a slave is addressed in this fashion with the full 10-bit address (we will refer to this state as "PRIOR_ADDR_MATCH"), the master can begin sending data bytes for a slave reception operation.

14.4.2 10-BIT MODE SLAVE RECEPTION

Once addressed, the master can generate a Repeated Start, reset the high byte of the address and set the R_W bit without generating a Stop bit, thus initiating a slave transmit operation.

14.5 Automatic Clock Stretch

In the Slave modes, the module can synchronize buffer reads and write to the master device by clock stretching.

14.5.1 TRANSMIT CLOCK STRETCHING

Both 10-bit and 7-bit Transmit modes implement clock stretching by asserting the SCLREL bit after the falling edge of the ninth clock, if the TBF bit is cleared, indicating the buffer is empty.

In Slave Transmit modes, clock stretching is always performed irrespective of the STREN bit.

Clock synchronization takes place following the ninth clock of the transmit sequence. If the device samples an ACK on the falling edge of the ninth clock and if the TBF bit is still clear, then the SCLREL bit is automatically cleared. The SCLREL being cleared to '0' will assert the SCL line low. The user's ISR must set the SCLREL bit before transmission is allowed to continue. By holding the SCL line low, the user has time to service the ISR and load the contents of the I2CTRN before the master device can initiate another transmit sequence.

Note 1: If the user loads the contents of I2CTRN, setting the TBF bit before the falling edge of the ninth clock, the SCLREL bit will not be cleared and clock stretching will not occur.

2: The SCLREL bit can be set in software, regardless of the state of the TBF bit.

14.5.2 RECEIVE CLOCK STRETCHING

The STREN bit in the I2CCON register can be used to enable clock stretching in Slave Receive mode. When the STREN bit is set, the SCL pin will be held low at the end of each data receive sequence.

14.5.3 CLOCK STRETCHING DURING 7-BIT ADDRESSING (STREN = 1)

When the STREN bit is set in Slave Receive mode, the SCL line is held low when the buffer register is full. The method for stretching the SCL output is the same for both 7 and 10-bit addressing modes.

Clock stretching takes place following the ninth clock of the receive sequence. On the falling edge of the ninth clock at the end of the ACK sequence, if the RBF bit is set, the SCLREL bit is automatically cleared, forcing the SCL output to be held low. The user's ISR must set the SCLREL bit before reception is allowed to continue. By holding the SCL line low, the user has time to service the ISR and read the contents of the I2CRCV before the master device can initiate another receive sequence. This will prevent buffer overruns from occurring.

Note 1: If the user reads the contents of the I2CRCV, clearing the RBF bit before the falling edge of the ninth clock, the SCLREL bit will not be cleared and clock stretching will not occur.

2: The SCLREL bit can be set in software regardless of the state of the RBF bit. The user should be careful to clear the RBF bit in the ISR before the next receive sequence in order to prevent an overflow condition.

14.5.4 CLOCK STRETCHING DURING 10-BIT ADDRESSING (STREN = 1)

Clock stretching takes place automatically during the addressing sequence. Because this module has a register for the entire address, it is not necessary for the protocol to wait for the address to be updated.

After the address phase is complete, clock stretching will occur on each data receive or transmit sequence as was described earlier.

14.6 Software Controlled Clock Stretching (STREN = 1)

When the STREN bit is '1', the SCLREL bit may be cleared by software to allow software to control the clock stretching. The logic will synchronize writes to the SCLREL bit with the SCL clock. Clearing the SCLREL bit will not assert the SCL output until the module detects a falling edge on the SCL output and SCL is sampled low. If the SCLREL bit is cleared by the user while the SCL line has been sampled low, the SCL output will be asserted (held low). The SCL output will remain low until the SCLREL bit is set, and all other devices on the I²C bus have de-asserted SCL. This ensures that a write to the SCLREL bit will not violate the minimum high time requirement for SCL.

If the STREN bit is '0', a software write to the SCLREL bit will be disregarded and have no effect on the SCLREL bit.

14.7 Interrupts

The I²C module generates two interrupt flags, MI2CIF (I²C Master Interrupt Flag) and SI2CIF (I²C Slave Interrupt Flag). The MI2CIF interrupt flag is activated on completion of a master message event. The SI2CIF interrupt flag is activated on detection of a message directed to the slave.

14.8 Slope Control

The I²C standard requires slope control on the SDA and SCL signals for Fast mode (400 kHz). The control bit, DISSLW, enables the user to disable slew rate control if desired. It is necessary to disable the slew rate control for 1 MHz mode.

14.9 IPMI Support

The control bit, IPMIEN, enables the module to support Intelligent Peripheral Management Interface (IPMI). When this bit is set, the module accepts and acts upon all addresses.

14.10 General Call Address Support

The general call address can address all devices. When this address is used, all devices should, in theory, respond with an acknowledgement.

The general call address is one of eight addresses reserved for specific purposes by the I²C protocol. It consists of all '0's with R_W = 0.

The general call address is recognized when the General Call Enable (GCEN) bit is set (I2CCON<7> = 1). Following a Start bit detection, 8 bits are shifted into I2CRSR and the address is compared with I2CADD, and is also compared with the general call address which is fixed in hardware.

If a general call address match occurs, the I2CRSR is transferred to the I2CRCV after the eighth clock, the RBF flag is set and on the falling edge of the ninth bit ($\overline{\text{ACK}}$ bit), the master event interrupt flag (MI2CIF) is set.

When the interrupt is serviced, the source for the interrupt can be checked by reading the contents of the I2CRCV to determine if the address was device specific or a general call address.

14.11 I²C Master Support

As a master device, six operations are supported:

- Assert a Start condition on SDA and SCL.
- Assert a Restart condition on SDA and SCL.
- Write to the I2CTRN register initiating transmission of data/address.
- Generate a Stop condition on SDA and SCL.
- Configure the I²C port to receive data.
- Generate an $\overline{\text{ACK}}$ condition at the end of a received byte of data.

14.12 I²C Master Operation

The master device generates all of the serial clock pulses and the Start and Stop conditions. A transfer is ended with a Stop condition or with a Repeated Start condition. Since the Repeated Start condition is also the beginning of the next serial transfer, the I²C bus will not be released.

In Master Transmitter mode, serial data is output through SDA, while SCL outputs the serial clock. The first byte transmitted contains the slave address of the receiving device (7 bits) and the data direction bit. In this case, the data direction bit (R_W) is logic '0'. Serial data is transmitted 8 bits at a time. After each byte is transmitted, an $\overline{\text{ACK}}$ bit is received. Start and Stop conditions are output to indicate the beginning and the end of a serial transfer.

In Master Receive mode, the first byte transmitted contains the slave address of the transmitting device (7 bits) and the data direction bit. In this case, the data direction bit (R_W) is logic '1'. Thus, the first byte transmitted is a 7-bit slave address, followed by a '1' to indicate receive bit. Serial data is received via SDA while SCL outputs the serial clock. Serial data is received 8 bits at a time. After each byte is received, an $\overline{\text{ACK}}$ bit is transmitted. Start and Stop conditions indicate the beginning and end of transmission.

14.12.1 I²C MASTER TRANSMISSION

Transmission of a data byte, a 7-bit address, or the second half of a 10-bit address, is accomplished by simply writing a value to I2CTRN register. The user should only write to I2CTRN when the module is in a WAIT state. This action will set the Buffer Full Flag (TBF) and allow the Baud Rate Generator to begin counting and start the next transmission. Each bit of address/data will be shifted out onto the SDA pin after the falling edge of SCL is asserted. The Transmit Status Flag, TRSTAT (I2CSTAT<14>), indicates that a master transmit is in progress.

14.12.2 I²C MASTER RECEPTION

Master mode reception is enabled by programming the Receive Enable bit, RCEN (I2CCON<3>). The I²C module must be Idle before the RCEN bit is set, otherwise the RCEN bit will be disregarded. The Baud Rate Generator begins counting and on each rollover, the state of the SCL pin $\overline{\text{ACK}}$ and data are shifted into the I2CRSR on the rising edge of each clock.

14.12.3 BAUD RATE GENERATOR

In I²C Master mode, the reload value for the BRG is located in the I2CBRG register. When the BRG is loaded with this value, the BRG counts down to '0' and stops until another reload has taken place. If clock arbitration is taking place, for instance, the BRG is reloaded when the SCL pin is sampled high.

As per the I²C standard, FSCK may be 100 kHz or 400 kHz. However, the user can specify any baud rate up to 1 MHz. I2CBRG values of '0' or '1' are illegal.

EQUATION 14-1: SERIAL CLOCK RATE

$$I2CBRG = \left(\frac{FCY}{F_{SCL}} - \frac{FCY}{1,111,111} \right) - 1$$

14.12.4 CLOCK ARBITRATION

Clock arbitration occurs when the master de-asserts the SCL pin (SCL allowed to float high) during any receive, transmit, or Restart/Stop condition. When the SCL pin is allowed to float high, the Baud Rate Generator (BRG) is suspended from counting until the SCL pin is actually sampled high. When the SCL pin is sampled high, the Baud Rate Generator is reloaded with the contents of I2CBRG and begins counting. This ensures that the SCL high time will always be at least one BRG rollover count in the event that the clock is held low by an external device.

14.12.5 MULTI-MASTER COMMUNICATION, BUS COLLISION, AND BUS ARBITRATION

Multi-master operation support is achieved by bus arbitration. When the master outputs address/data bits onto the SDA pin, arbitration takes place when the master outputs a '1' on SDA by letting SDA float high while another master asserts a '0'. When the SCL pin floats high, data should be stable. If the expected data on SDA is a '1' and the data sampled on the SDA pin = 0, then a bus collision has taken place. The master will set the MI2CIF pulse and reset the master portion of the I²C port to its Idle state.

If a transmit was in progress when the bus collision occurred, the transmission is halted, the TBF flag is cleared, the SDA and SCL lines are de-asserted and a value can now be written to I2CTRN. When the user services the I²C master event Interrupt Service Routine, if the I²C bus is free (i.e., the P bit is set), the user can resume communication by asserting a Start condition.

If a Start, Restart, Stop or Acknowledge condition was in progress when the bus collision occurred, the condition is aborted, the SDA and SCL lines are de-asserted, and the respective control bits in the I2CCON register are cleared to '0'. When the user services the bus collision Interrupt Service Routine, and if the I²C bus is free, the user can resume communication by asserting a Start condition.

The master will continue to monitor the SDA and SCL pins, and if a Stop condition occurs, the MI2CIF bit will be set.

A write to the I2CTRN will start the transmission of data at the first data bit regardless of where the transmitter left off when bus collision occurred.

In a multi-master environment, the interrupt generation on the detection of Start and Stop conditions allows the determination of when the bus is free. Control of the I²C bus can be taken when the P bit is set in the I2CSTAT register, or the bus is Idle and the S and P bits are cleared.

14.13 I²C Module Operation During CPU Sleep and Idle Modes

14.13.1 I²C OPERATION DURING CPU SLEEP MODE

When the device enters Sleep mode, all clock sources to the module are shut down and stay at logic '0'. If Sleep occurs in the middle of a transmission and the state machine is partially into a transmission as the clocks stop, then the transmission is aborted. Similarly, if Sleep occurs in the middle of a reception, then the reception is aborted.

14.13.2 I²C OPERATION DURING CPU IDLE MODE

For the I²C, the I2CSIDL bit selects if the module will stop on Idle or continue on Idle. If I2CSIDL = 0, the module will continue operation on assertion of the Idle mode. If I2CSIDL = 1, the module will stop on Idle.

TABLE 14-2: I²C REGISTER MAP

| SFR Name | Addr. | Bit 15 | Bit 14 | Bit 13 | Bit 12 | Bit 11 | Bit 10 | Bit 9 | Bit 8 | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Reset State |
|----------|-------|---------|--------|---------|--------|--------|--------|--------|-------|---------------------|-------|-------|-------|-------|-------|-------|-------|---------------------|
| I2CRCV | 0200 | — | — | — | — | — | — | — | — | Receive Register | | | | | | | | 0000 0000 0000 0000 |
| I2CTRN | 0202 | — | — | — | — | — | — | — | — | Transmit Register | | | | | | | | 0000 0000 1111 1111 |
| I2CBRG | 0204 | — | — | — | — | — | — | — | — | Baud Rate Generator | | | | | | | | 0000 0000 0000 0000 |
| I2CCON | 0206 | I2CEN | — | I2CSIDL | SCLREL | IPMIEN | A10M | DISSLW | SMEN | GCEN | STREN | ACKDT | ACKEN | RCEN | PEN | RSEN | SEN | 0001 0000 0000 0000 |
| I2CSTAT | 0208 | ACKSTAT | TRSTAT | — | — | — | BCL | GCSTAT | ADD10 | IWCOL | I2COV | D_A | P | S | R_W | RBF | TBF | 0000 0000 0000 0000 |
| I2CADD | 020A | — | — | — | — | — | — | — | — | Address Register | | | | | | | | 0000 0000 0000 0000 |

Legend: — = unimplemented bit, read as '0'
Note: Refer to the "dsPIC30F Family Reference Manual" (DS70046) for descriptions of register bit fields.

NOTES:

15.0 UNIVERSAL ASYNCHRONOUS RECEIVER TRANSMITTER (UART) MODULE

Note: This data sheet summarizes features of this group of dsPIC30F devices and is not intended to be a complete reference source. For more information on the CPU, peripherals, register descriptions and general device functionality, refer to the “dsPIC30F Family Reference Manual” (DS70046).

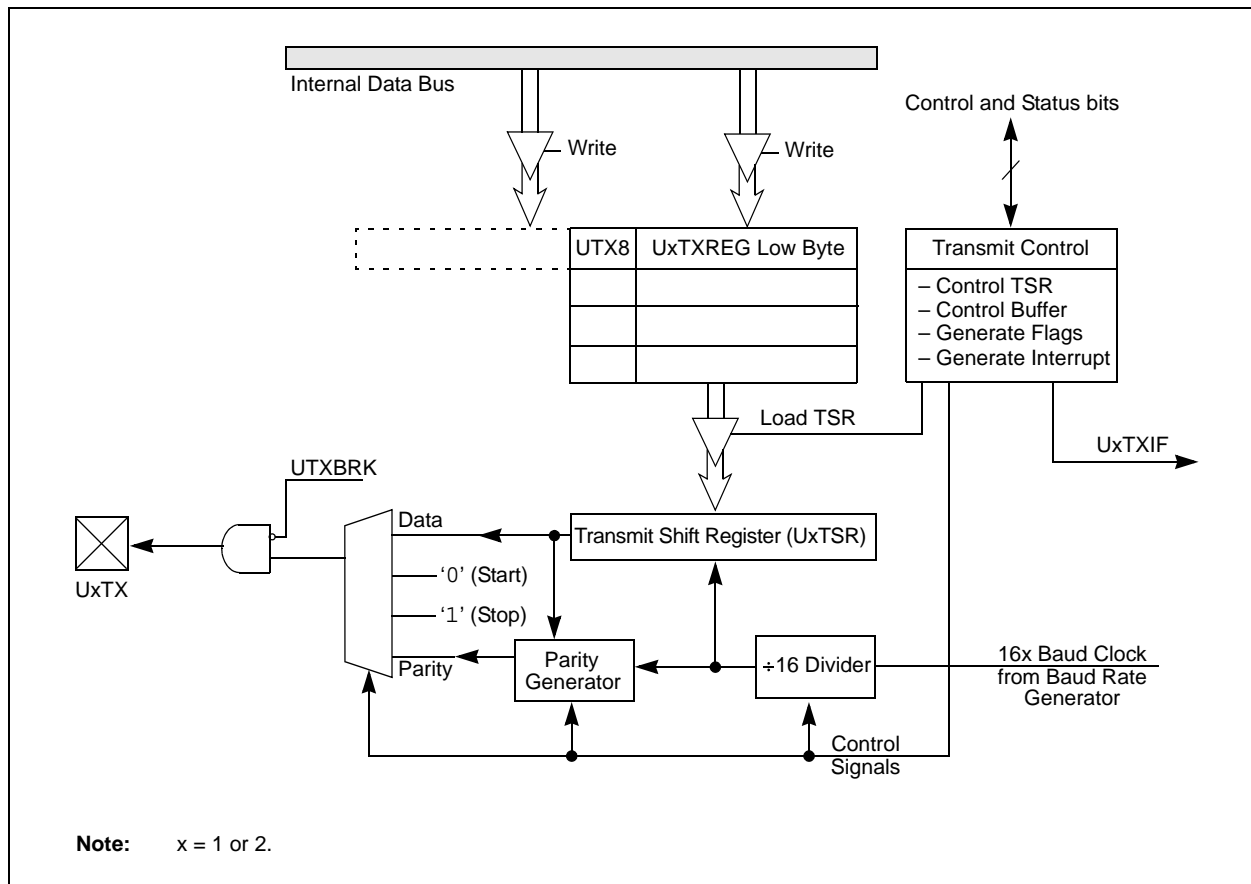
This section describes the Universal Asynchronous Receiver/Transmitter Communications module. The dsPIC30F2011/2012/3012 processors have one UART module (UART1). The dsPIC30F3013 processor has two UART modules (UART1 and UART2).

15.1 UART Module Overview

The key features of the UART module are:

- Full-duplex, 8 or 9-bit data communication
- Even, odd or no parity options (for 8-bit data)
- One or two Stop bits
- Fully integrated Baud Rate Generator with 16-bit prescaler
- Baud rates range from 38 bps to 1.875 Mbps at a 30 MHz instruction rate
- 4-word deep transmit data buffer
- 4-word deep receive data buffer
- Parity, framing and buffer overrun error detection
- Support for interrupt only on address detect (9th bit = 1)
- Separate transmit and receive interrupts
- Loopback mode for diagnostic support
- Alternate receive and transmit pins for UART1

FIGURE 15-1: UART TRANSMITTER BLOCK DIAGRAM



| |
|--|
| |
|--|



15.2 Enabling and Setting Up UART

15.2.1 ENABLING THE UART

The UART module is enabled by setting the UARTEN bit in the UxMODE register (where x = 1 or 2). Once enabled, the UxTX and UxRX pins are configured as an output and an input respectively, overriding the TRIS and LAT register bit settings for the corresponding I/O port pins. The UxTX pin is at logic '1' when no transmission is taking place.

15.2.2 DISABLING THE UART

The UART module is disabled by clearing the UARTEN bit in the UxMODE register. This is the default state after any Reset. If the UART is disabled, all I/O pins operate as port pins under the control of the LAT and TRIS bits of the corresponding port pins.

Disabling the UART module resets the buffers to empty states. Any data characters in the buffers are lost and the baud rate counter is reset.

All error and status flags associated with the UART module are reset when the module is disabled. The URXDA, OERR, FERR, PERR, UTXEN, UTXBRK and UTXBF bits are cleared, whereas RIDLE and TRMT are set. Other control bits, including ADDEN, URXISEL<1:0>, UTXISEL, as well as the UxMODE and UxBRG registers, are not affected.

Clearing the UARTEN bit while the UART is active will abort all pending transmissions and receptions and reset the module as defined above. Re-enabling the UART will restart the UART in the same configuration.

15.2.3 ALTERNATE I/O

The alternate I/O function is enabled by setting the ALTIO bit (UxMODE<10>). If ALTIO = 1, the UxATX and UxARX pins (alternate transmit and alternate receive pins, respectively) are used by the UART module instead of the UxTX and UxRX pins. If ALTIO = 0, the UxTX and UxRX pins are used by the UART module.

15.2.4 SETTING UP DATA, PARITY AND STOP BIT SELECTIONS

Control bits PDSEL<1:0> in the UxMODE register are used to select the data length and parity used in the transmission. The data length may either be 8 bits with even, odd or no parity, or 9 bits with no parity.

The STSEL bit determines whether one or two Stop bits will be used during data transmission.

The default (power-on) setting of the UART is 8 bits, no parity and 1 Stop bit (typically represented as 8, N, 1).

15.3 Transmitting Data

15.3.1 TRANSMITTING IN 8-BIT DATA MODE

The following steps must be performed to transmit 8-bit data:

1. Set up the UART:
First, the data length, parity and number of Stop bits must be selected. Then, the transmit and receive interrupt enable and priority bits are setup in the UxMODE and UxSTA registers. Also, the appropriate baud rate value must be written to the UxBRG register.
2. Enable the UART by setting the UARTEN bit (UxMODE<15>).
3. Set the UTXEN bit (UxSTA<10>), thereby enabling a transmission.
4. Write the byte to be transmitted to the lower byte of UxTXREG. The value will be transferred to the Transmit Shift register (UxTSR) immediately and the serial bit stream will start shifting out during the next rising edge of the baud clock. Alternatively, the data byte may be written while UTXEN = 0, following which, the user may set UTXEN. This will cause the serial bit stream to begin immediately because the baud clock will start from a cleared state.
5. A transmit interrupt will be generated, depending on the value of the interrupt control bit UTXISEL (UxSTA<15>).

15.3.2 TRANSMITTING IN 9-BIT DATA MODE

The sequence of steps involved in the transmission of 9-bit data is similar to 8-bit transmission, except that a 16-bit data word (of which the upper 7 bits are always clear) must be written to the UxTXREG register.

15.3.3 TRANSMIT BUFFER (UxTXB)

The transmit buffer is 9 bits wide and 4 characters deep. Including the Transmit Shift register (UxTSR), the user effectively has a 5-deep FIFO (First-In, First-Out) buffer. The UTXBF bit (UxSTA<9>) indicates whether the transmit buffer is full.

If a user attempts to write to a full buffer, the new data will not be accepted into the FIFO and no data shift will occur within the buffer. This enables recovery from a buffer overrun condition.

The FIFO is reset during any device Reset, but is not affected when the device enters or wakes up from a Power Saving mode.

15.3.4 TRANSMIT INTERRUPT

The transmit interrupt flag (U1TXIF or U2TXIF) is located in the corresponding interrupt flag register.

The transmitter generates an edge to set the UxTXIF bit. The condition for generating the interrupt depends on the UTXISEL control bit:

- a) If UTXISEL = 0, an interrupt is generated when a word is transferred from the transmit buffer to the Transmit Shift register (UxTSR). This means that the transmit buffer has at least one empty word.
- b) If UTXISEL = 1, an interrupt is generated when a word is transferred from the transmit buffer to the Transmit Shift register (UxTSR) and the transmit buffer is empty.

Switching between the two Interrupt modes during operation is possible and sometimes offers more flexibility.

15.3.5 TRANSMIT BREAK

Setting the UTXBRK bit (UxSTA<11>) will cause the UxTX line to be driven to logic '0'. The UTXBRK bit overrides all transmission activity. Therefore, the user should generally wait for the transmitter to be Idle before setting UTXBRK.

To send a Break character, the UTXBRK bit must be set by software and must remain set for a minimum of 13 baud clock cycles. The UTXBRK bit is then cleared by software to generate Stop bits. The user must wait for a duration of at least one or two baud clock cycles in order to ensure a valid Stop bit(s) before reloading the UxTXB, or starting other transmitter activity. Transmission of a Break character does not generate a transmit interrupt.

15.4 Receiving Data

15.4.1 RECEIVING IN 8-BIT OR 9-BIT DATA MODE

The following steps must be performed while receiving 8-bit or 9-bit data:

1. Set up the UART (see [Section 15.3.1 "Transmitting in 8-bit data mode"](#)).
2. Enable the UART (see [Section 15.3.1 "Transmitting in 8-bit data mode"](#)).
3. A receive interrupt will be generated when one or more data words have been received, depending on the receive interrupt settings specified by the URXISEL bits (UxSTA<7:6>).
4. Read the OERR bit to determine if an overrun error has occurred. The OERR bit must be reset in software.
5. Read the received data from UxRXREG. The act of reading UxRXREG will move the next word to the top of the receive FIFO, and the PERR and FERR values will be updated.

15.4.2 RECEIVE BUFFER (UxRXB)

The receive buffer is 4 words deep. Including the Receive Shift register (UxRSR), the user effectively has a 5-word deep FIFO buffer.

URXDA (UxSTA<0>) = 1 indicates that the receive buffer has data available. URXDA = 0 implies that the buffer is empty. If a user attempts to read an empty buffer, the old values in the buffer will be read and no data shift will occur within the FIFO.

The FIFO is reset during any device Reset. It is not affected when the device enters or wakes up from a Power Saving mode.

15.4.3 RECEIVE INTERRUPT

The receive interrupt flag (U1RXIF or U2RXIF) can be read from the corresponding interrupt flag register. The interrupt flag is set by an edge generated by the receiver. The condition for setting the receive interrupt flag depends on the settings specified by the URXISEL<1:0> (UxSTA<7:6>) control bits.

- a) If URXISEL<1:0> = 00 or 01, an interrupt is generated every time a data word is transferred from the Receive Shift register (UxRSR) to the receive buffer. There may be one or more characters in the receive buffer.
- b) If URXISEL<1:0> = 10, an interrupt is generated when a word is transferred from the Receive Shift register (UxRSR) to the receive buffer, which as a result of the transfer, contains 3 characters.
- c) If URXISEL<1:0> = 11, an interrupt is set when a word is transferred from the Receive Shift register (UxRSR) to the receive buffer, which as a result of the transfer, contains 4 characters (i.e., becomes full).

Switching between the Interrupt modes during operation is possible, though generally not advisable during normal operation.

15.5 Reception Error Handling

15.5.1 RECEIVE BUFFER OVERRUN ERROR (OERR BIT)

The OERR bit (UxSTA<1>) is set if all of the following conditions occur:

- a) The receive buffer is full.
- b) The Receive Shift register is full, but unable to transfer the character to the receive buffer.
- c) The Stop bit of the character in the UxRSR is detected, indicating that the UxRSR needs to transfer the character to the buffer.

Once OERR is set, no further data is shifted in UxRSR (until the OERR bit is cleared in software or a Reset occurs). The data held in UxRSR and UxRXREG remains valid.

15.5.2 FRAMING ERROR (FERR)

The FERR bit (UxSTA<2>) is set if a '0' is detected instead of a Stop bit. If two Stop bits are selected, both Stop bits must be '1', otherwise FERR will be set. The read-only FERR bit is buffered along with the received data. It is cleared on any Reset.

15.5.3 PARITY ERROR (PERR)

The PERR bit (UxSTA<3>) is set if the parity of the received word is incorrect. This error bit is applicable only if a Parity mode (odd or even) is selected. The read-only PERR bit is buffered along with the received data bytes. It is cleared on any Reset.

15.5.4 IDLE STATUS

When the receiver is active (i.e., between the initial detection of the Start bit and the completion of the Stop bit), the RIDLE bit (UxSTA<4>) is '0'. Between the completion of the Stop bit and detection of the next Start bit, the RIDLE bit is '1', indicating that the UART is Idle.

15.5.5 RECEIVE BREAK

The receiver will count and expect a certain number of bit times based on the values programmed in the PDSEL (UxMODE<2:1>) and STSEL (UxMODE<0>) bits.

If the break is longer than 13 bit times, the reception is considered complete after the number of bit times specified by PDSEL and STSEL. The URXDA bit is set, FERR is set, zeros are loaded into the receive FIFO, interrupts are generated if appropriate and the RIDLE bit is set.

When the module receives a long break signal and the receiver has detected the Start bit, the data bits and the invalid Stop bit (which sets the FERR), the receiver must wait for a valid Stop bit before looking for the next Start bit. It cannot assume that the break condition on the line is the next Start bit.

Break is regarded as a character containing all '0's with the FERR bit set. The Break character is loaded into the buffer. No further reception can occur until a Stop bit is received. Note that RIDLE goes high when the Stop bit has not yet been received.

15.6 Address Detect Mode

Setting the ADDEN bit (UxSTA<5>) enables this special mode in which a 9th bit (URX8) value of '1' identifies the received word as an address, rather than data. This mode is only applicable for 9-bit data communication. The URXISEL control bit does not have any impact on interrupt generation in this mode since an interrupt (if enabled) will be generated every time the received word has the 9th bit set.

15.7 Loopback Mode

Setting the LPBACK bit enables this special mode in which the UxTX pin is internally connected to the UxRX pin. When configured for the Loopback mode, the UxRX pin is disconnected from the internal UART receive logic. However, the UxTX pin still functions as in a normal operation.

To select this mode:

- Configure UART for desired mode of operation.
- Set LPBACK = 1 to enable Loopback mode.
- Enable transmission as defined in [Section 15.3 "Transmitting Data"](#).

15.8 Baud Rate Generator

The UART has a 16-bit Baud Rate Generator to allow maximum flexibility in baud rate generation. The Baud Rate Generator register (UxBRG) is readable and writable. The baud rate is computed as follows:

BRG = 16-bit value held in UxBRG register
(0 through 65535)

FCY = Instruction Clock Rate (1/Tcy)

The baud rate is given by [Equation 15-1](#).

EQUATION 15-1: BAUD RATE

$$\text{Baud Rate} = \text{FCY} / (16 * (\text{BRG} + 1))$$

Therefore, the maximum baud rate possible is:

$\text{FCY} / 16$ (if BRG = 0),

and the minimum baud rate possible is:

$\text{FCY} / (16 * 65536)$.

With a full 16-bit Baud Rate Generator at 30 MIPS operation, the minimum baud rate achievable is 28.5 bps.

15.9 Auto-Baud Support

To allow the system to determine baud rates of received characters, the input can be optionally linked to a selected capture input (IC1 for UART1 and IC2 for UART2). To enable this mode, you must program the input capture module to detect the falling and rising edges of the Start bit.

15.10 UART Operation During CPU Sleep and Idle Modes

15.10.1 UART OPERATION DURING CPU SLEEP MODE

When the device enters Sleep mode, all clock sources to the module are shut down and stay at logic '0'. If entry into Sleep mode occurs while a transmission is in progress, then the transmission is aborted. The UxTX pin is driven to logic '1'. Similarly, if entry into Sleep mode occurs while a reception is in progress, then the reception is aborted. The UxSTA, UxMODE, transmit and receive registers and buffers, and the UxBRG register are not affected by Sleep mode.

If the WAKE bit (UxMODE<7>) is set before the device enters Sleep mode, then a falling edge on the UxRX pin will generate a receive interrupt. The Receive Interrupt Select mode bit (URXISEL) has no effect for this function. If the receive interrupt is enabled, then this will wake-up the device from Sleep. The UARTEN bit must be set in order to generate a wake-up interrupt.

15.10.2 UART OPERATION DURING CPU IDLE MODE

For the UART, the USIDL bit selects if the module will stop operation when the device enters Idle mode or whether the module will continue on Idle. If USIDL = 0, the module will continue to operate during Idle mode. If USIDL = 1, the module will stop on Idle.

TABLE 15-1: UART1 REGISTER MAP FOR dsPIC30F2011/2012/3012/3013

| SFR Name | Addr. | Bit 15 | Bit 14 | Bit 13 | Bit 12 | Bit 11 | Bit 10 | Bit 9 | Bit 8 | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Reset State |
|----------|-------|-------------------------------|--------|--------|--------|--------|--------|-------|-------|-------------------|----------|-------|-------|-------|--------|--------|-------|---------------------|
| U1MODE | 020C | UARTEN | — | USIDL | — | — | ALTIO | — | — | WAKE | LPBACK | ABAUD | — | — | PDSEL1 | PDSEL0 | STSEL | 0000 0000 0000 0000 |
| U1STA | 020E | UTXISEL | — | — | — | UTXBRK | UTXEN | UTXBF | TRMT | URXISEL1 | URXISEL0 | ADDEN | RIDLE | PERR | FERR | OERR | URXDA | 0000 0001 0001 0000 |
| U1TXREG | 0210 | — | — | — | — | — | — | — | UTX8 | Transmit Register | | | | | | | | 0000 000u uuuu uuuu |
| U1RXREG | 0212 | — | — | — | — | — | — | — | URX8 | Receive Register | | | | | | | | 0000 0000 0000 0000 |
| U1BRG | 0214 | Baud Rate Generator Prescaler | | | | | | | | | | | | | | | | 0000 0000 0000 0000 |

Legend: u = uninitialized bit; — = unimplemented bit, read as '0'

TABLE 15-2: UART2 REGISTER MAP FOR dsPIC30F3013⁽¹⁾

| SFR Name | Addr. | Bit 15 | Bit 14 | Bit 13 | Bit 12 | Bit 11 | Bit 10 | Bit 9 | Bit 8 | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Reset State |
|----------|-------|-------------------------------|--------|--------|--------|--------|--------|-------|-------|-------------------|----------|-------|-------|-------|--------|--------|-------|---------------------|
| U2MODE | 0216 | UARTEN | — | USIDL | — | — | — | — | — | WAKE | LPBACK | ABAUD | — | — | PDSEL1 | PDSEL0 | STSEL | 0000 0000 0000 0000 |
| U2STA | 0218 | UTXISEL | — | — | — | UTXBRK | UTXEN | UTXBF | TRMT | URXISEL1 | URXISEL0 | ADDEN | RIDLE | PERR | FERR | OERR | URXDA | 0000 0001 0001 0000 |
| U2TXREG | 021A | — | — | — | — | — | — | — | UTX8 | Transmit Register | | | | | | | | 0000 000u uuuu uuuu |
| U2RXREG | 021C | — | — | — | — | — | — | — | URX8 | Receive Register | | | | | | | | 0000 0000 0000 0000 |
| U2BRG | 021E | Baud Rate Generator Prescaler | | | | | | | | | | | | | | | | 0000 0000 0000 0000 |

Legend: u = uninitialized bit; — = unimplemented bit, read as '0'

- Note 1:** UART2 is not available on dsPIC30F2011/2012/3012 devices.
Note 2: Refer to the “dsPIC30F Family Reference Manual” (DS70046) for descriptions of register bit fields.

NOTES:

16.0 12-BIT ANALOG-TO-DIGITAL CONVERTER (ADC) MODULE

Note: This data sheet summarizes features of this group of dsPIC30F devices and is not intended to be a complete reference source. For more information on the CPU, peripherals, register descriptions and general device functionality, refer to the "dsPIC30F Family Reference Manual" (DS70046).

The 12-bit Analog-to-Digital Converter allows conversion of an analog input signal to a 12-bit digital number. This module is based on a Successive Approximation Register (SAR) architecture and provides a maximum sampling rate of 200 ksp/s. The ADC module has up to 10 analog inputs which are multiplexed into a sample and hold amplifier. The output of the sample and hold is the input into the converter which generates the result. The analog reference voltage is software selectable to either the device supply voltage (AVDD/AVSS) or the voltage level on the (VREF+/VREF-) pin. The ADC has a unique feature of being able to operate while the device is in Sleep mode with RC oscillator selection.

The ADC module has six 16-bit registers:

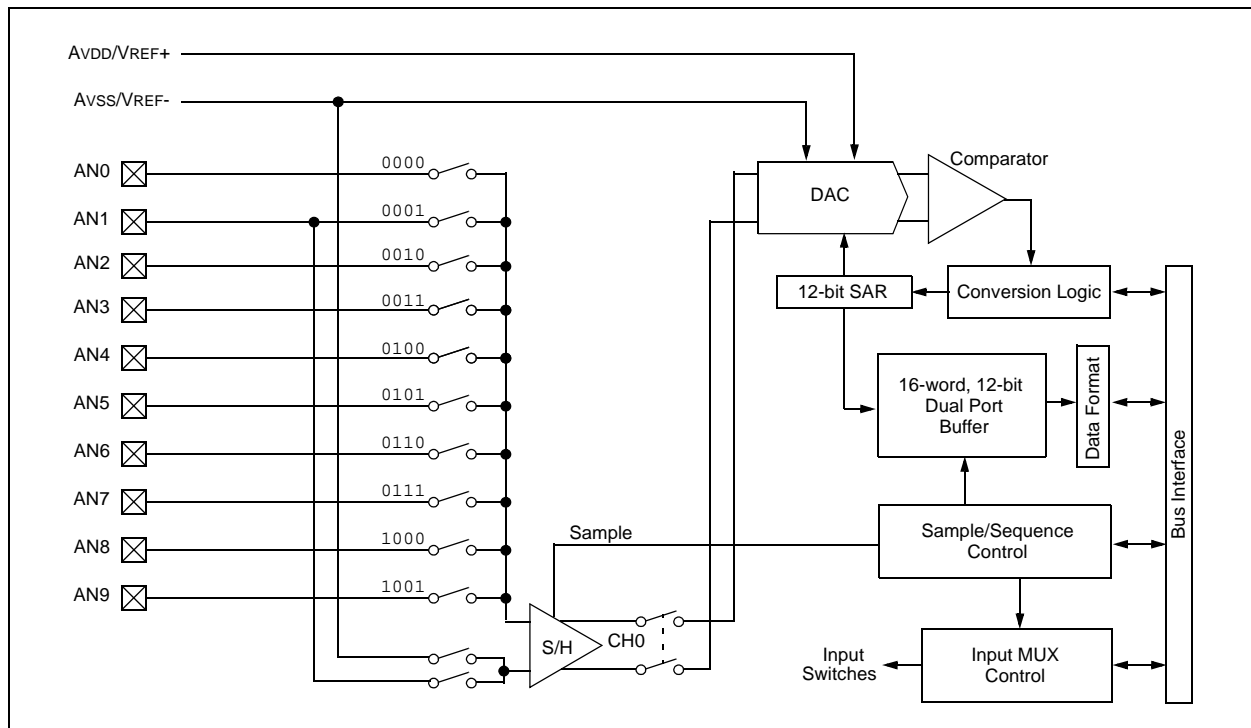
- A/D Control Register 1 (ADCON1)
- A/D Control Register 2 (ADCON2)
- A/D Control Register 3 (ADCON3)
- A/D Input Select Register (ADCHS)
- A/D Port Configuration Register (ADPCFG)
- A/D Input Scan Selection Register (ADCSSL)

The ADCON1, ADCON2 and ADCON3 registers control the operation of the ADC module. The ADCHS register selects the input channels to be converted. The ADPCFG register configures the port pins as analog inputs or as digital I/O. The ADCSSL register selects inputs for scanning.

Note: The SSR<2:0>, ASAM, SMPI<3:0>, BUFM and ALTS bits, as well as the ADCON3 and ADCSSL registers, must not be written to while ADON = 1. This would lead to indeterminate results.

The block diagram of the 12-bit ADC module is shown in Figure 16-1.

FIGURE 16-1: 12-BIT ADC FUNCTIONAL BLOCK DIAGRAM



16.1 A/D Result Buffer

The module contains a 16-word dual port read-only buffer, called ADCBUF0...ADCBUFF, to buffer the A/D results. The RAM is 12 bits wide but the data obtained is represented in one of four different 16-bit data formats. The contents of the sixteen A/D Conversion Result Buffer registers, ADCBUF0 through ADCBUFF, cannot be written by user software.

16.2 Conversion Operation

After the ADC module has been configured, the sample acquisition is started by setting the SAMP bit. Various sources, such as a programmable bit, timer time-outs and external events, will terminate acquisition and start a conversion. When the A/D conversion is complete, the result is loaded into ADCBUF0...ADCBUFF, and the DONE bit and the A/D interrupt flag, ADIF, are set after the number of samples specified by the SMPI bit. The ADC module can be configured for different interrupt rates as described in [Section 16.3 “Selecting the Conversion Sequence”](#).

The following steps should be followed for doing an A/D conversion:

1. Configure the ADC module:
 - Configure analog pins, voltage reference and digital I/O
 - Select A/D input channels
 - Select A/D conversion clock
 - Select A/D conversion trigger
 - Turn on ADC module
2. Configure A/D interrupt (if required):
 - Clear ADIF bit
 - Select A/D interrupt priority
3. Start sampling
4. Wait the required acquisition time
5. Trigger acquisition end, start conversion
6. Wait for A/D conversion to complete, by either:
 - Waiting for the A/D interrupt, or
 - Waiting for the DONE bit to get set
7. Read A/D result buffer; clear ADIF if required

16.3 Selecting the Conversion Sequence

Several groups of control bits select the sequence in which the A/D connects inputs to the sample/hold channel, converts a channel, writes the buffer memory and generates interrupts.

The sequence is controlled by the sampling clocks.

The SMPI bits select the number of acquisition/conversion sequences that would be performed before an interrupt occurs. This can vary from 1 sample per interrupt to 16 samples per interrupt.

The BUFM bit will split the 16-word results buffer into two 8-word groups. Writing to the 8-word buffers will be alternated on each interrupt event.

Use of the BUFM bit will depend on how much time is available for the moving of the buffers after the interrupt.

If the processor can quickly unload a full buffer within the time it takes to acquire and convert one channel, the BUFM bit can be '0' and up to 16 conversions (corresponding to the 16 input channels) may be done per interrupt. The processor will have one acquisition and conversion time to move the sixteen conversions.

If the processor cannot unload the buffer within the acquisition and conversion time, the BUFM bit should be '1'. For example, if SMPI<3:0> (ADCON2<5:2>) = 0111, then eight conversions will be loaded into 1/2 of the buffer, following which an interrupt occurs. The next eight conversions will be loaded into the other 1/2 of the buffer. The processor will have the entire time between interrupts to move the eight conversions.

The ALTS bit can be used to alternate the inputs selected during the sampling sequence. The input multiplexer has two sets of sample inputs: MUX A and MUX B. If the ALTS bit is '0', only the MUX A inputs are selected for sampling. If the ALTS bit is '1' and SMPI<3:0> = 0000 on the first sample/convert sequence, the MUX A inputs are selected and on the next acquire/convert sequence, the MUX B inputs are selected.

The CSCNA bit (ADCON2<10>) will allow the multiplexer input to be alternately scanned across a selected number of analog inputs for the MUX A group. The inputs are selected by the ADCSSL register. If a particular bit in the ADCSSL register is '1', the corresponding input is selected. The inputs are always scanned from lower to higher numbered inputs, starting after each interrupt. If the number of inputs selected is greater than the number of samples taken per interrupt, the higher numbered inputs are unused.

16.4 Programming the Start of Conversion Trigger

The conversion trigger will terminate acquisition and start the requested conversions.

The SSRC<2:0> bits select the source of the conversion trigger. The SSRC bits provide for up to four alternate sources of conversion trigger.

When SSRC<2:0> = 000, the conversion trigger is under software control. Clearing the SAMP bit will cause the conversion trigger.

When SSRC<2:0> = 111 (Auto-Start mode), the conversion trigger is under A/D clock control. The SAMC bits select the number of A/D clocks between the start of acquisition and the start of conversion. This provides the fastest conversion rates on multiple channels. SAMC must always be at least one clock cycle.

Other trigger sources can come from timer modules or external interrupts.

16.5 Aborting a Conversion

Clearing the ADON bit during a conversion will abort the current conversion and stop the sampling sequencing until the next sampling trigger. The ADCBUF will not be updated with the partially completed A/D conversion sample. That is, the ADCBUF will continue to contain the value of the last completed conversion (or the last value written to the ADCBUF register).

If the clearing of the ADON bit coincides with an auto-start, the clearing has a higher priority and a new conversion will not start.

After the A/D conversion is aborted, a 2 TAD wait is required before the next sampling may be started by setting the SAMP bit.

16.6 Selecting the ADC Conversion Clock

The ADC conversion requires 14 TAD. The source of the ADC conversion clock is software selected, using a 6-bit counter. There are 64 possible options for TAD.

The internal RC oscillator is selected by setting the ADRC bit.

For correct ADC conversions, the ADC conversion clock (TAD) must be selected to ensure a minimum TAD time of 334 nsec (for VDD = 5V). Refer to [Section 20.0 "Electrical Characteristics"](#) for minimum TAD under other operating conditions.

[Example 16-1](#) shows a sample calculation for the ADCS<5:0> bits, assuming a device operating speed of 30 MIPS.

EXAMPLE 16-1: ADC CONVERSION CLOCK AND SAMPLING RATE CALCULATION

Minimum TAD = 334 nsec
TCY = 33.33 nsec (30 MIPS)

$$\begin{aligned} \text{ADCS}<5:0> &= 2 \frac{\text{TAD}}{\text{TCY}} - 1 \\ &= 2 \cdot \frac{334 \text{ nsec}}{33.33 \text{ nsec}} - 1 \\ &= 19.04 \end{aligned}$$

Therefore,
Set ADCS<5:0> = 19

$$\begin{aligned} \text{Actual TAD} &= \frac{\text{TCY}}{2} (\text{ADCS}<5:0> + 1) \\ &= \frac{33.33 \text{ nsec}}{2} (19 + 1) \\ &= 334 \text{ nsec} \end{aligned}$$

If SSRC<2:0> = '111' and SAMC<4:0> = '00001'

Since,

$$\begin{aligned} \text{Sampling Time} &= \text{Acquisition Time} + \text{Conversion Time} \\ &= 1 \text{ TAD} + 14 \text{ TAD} \\ &= 15 \times 334 \text{ nsec} \end{aligned}$$

Therefore,

$$\begin{aligned} \text{Sampling Rate} &= \frac{1}{(15 \times 334 \text{ nsec})} \\ &= \sim 200 \text{ kHz} \end{aligned}$$

EQUATION 16-1: ADC CONVERSION CLOCK

$$\text{TAD} = \text{TCY} * (0.5 * (\text{ADCS}<5:0> + 1))$$

dsPIC30F2011/2012/3012/3013

16.7 ADC Speeds

The dsPIC30F 12-bit ADC specifications permit a maximum of 200 ksp/s sampling rate. [Table 16-1](#) summarizes the conversion speeds for the dsPIC30F 12-bit ADC and the required operating conditions.

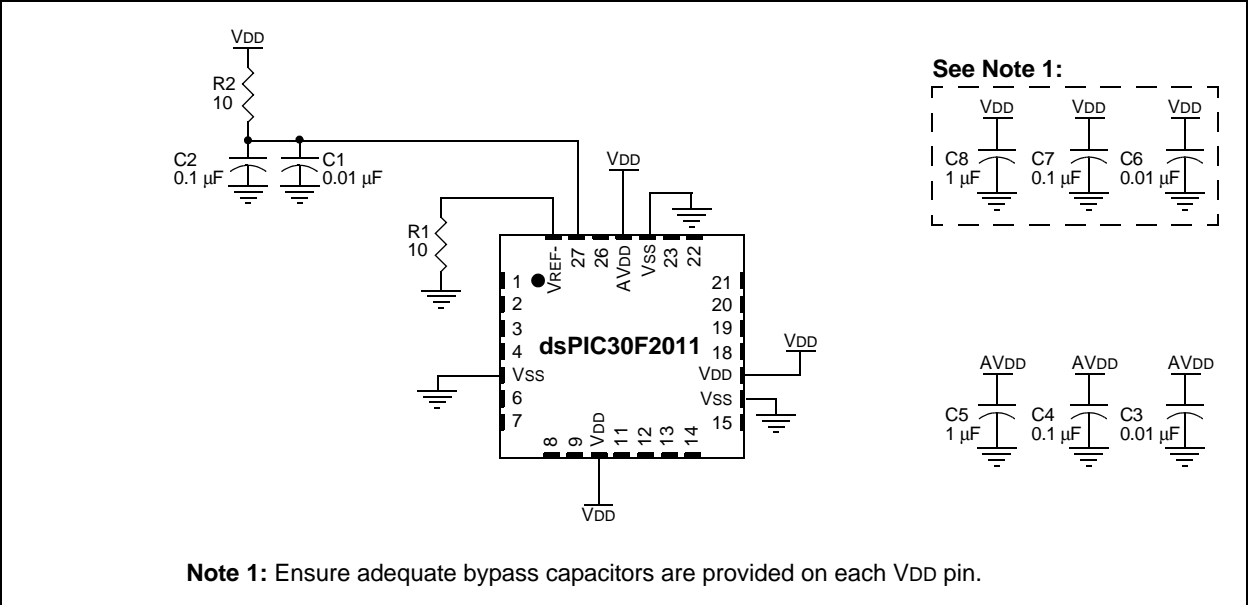
[Figure 16-2](#) depicts the recommended circuit for the conversion rates above 200 ksp/s. The dsPIC30F2011 is shown as an example.

TABLE 16-1: 12-BIT ADC EXTENDED CONVERSION RATES

| dsPIC30F 12-bit ADC Conversion Rates | | | | | | |
|--------------------------------------|-------------|-------------------|--------------------|--------------|-----------------|-----------------------|
| Speed | TAD Minimum | Sampling Time Min | R _s Max | VDD | Temperature | Channel Configuration |
| Up to 200 ksp/s ⁽¹⁾ | 334 ns | 1 TAD | 2.5 kΩ | 4.5V to 5.5V | -40°C to +85°C | |
| Up to 100 ksp/s | 668 ns | 1 TAD | 2.5 kΩ | 3.0V to 5.5V | -40°C to +125°C | |

Note 1: External VREF- and VREF+ pins must be used for correct operation. See [Figure 16-2](#) for recommended circuit.

FIGURE 16-2: ADC VOLTAGE REFERENCE SCHEMATIC



The configuration procedures in the next section provide the required setup values for the conversion speeds above 100 kps.

16.7.1 200 KSPS CONFIGURATION GUIDELINE

The following configuration items are required to achieve a 200 kps conversion rate.

- Comply with conditions provided in [Table 16-1](#).
- Connect external VREF+ and VREF- pins following the recommended circuit shown in [Figure 16-2](#).
- Set SSRC<2:0> = 111 in the ADCON1 register to enable the auto convert option.
- Enable automatic sampling by setting the ASAM control bit in the ADCON1 register.
- Write the SMP1<3:0> control bits in the ADCON2 register for the desired number of conversions between interrupts.
- Configure the ADC clock period to be:

$$\frac{1}{(14 + 1) \times 200,000} = 334 \text{ ns}$$

by writing to the ADCS<5:0> control bits in the ADCON3 register.

- Configure the sampling time to be 1 TAD by writing: SAMC<4:0> = 00001.

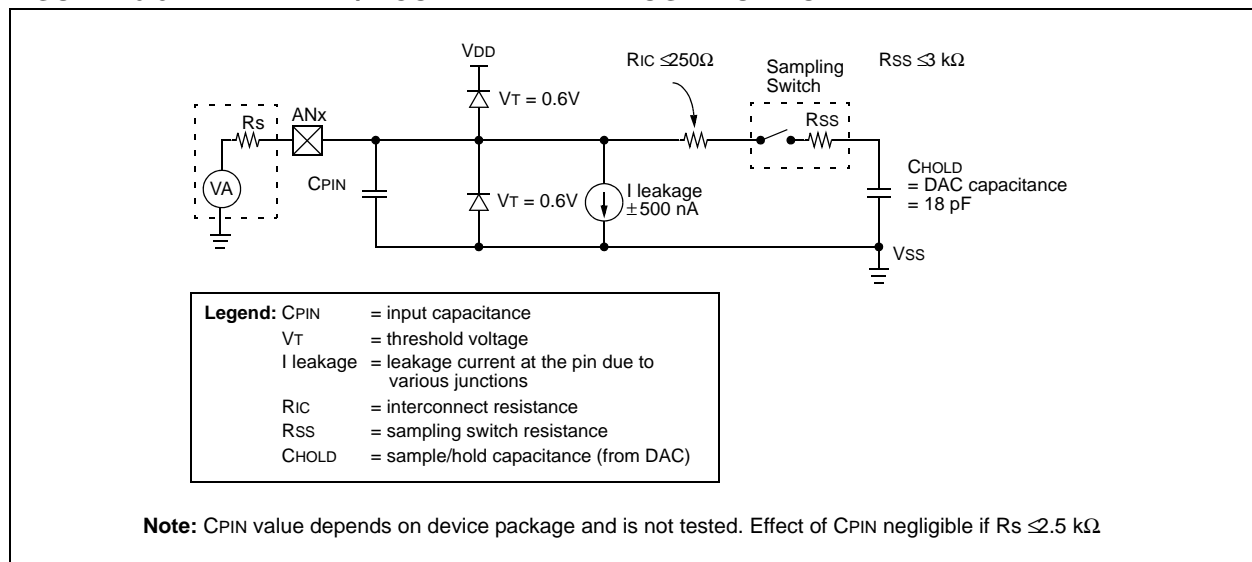
The following figure shows the timing diagram of the ADC running at 200 kps. The TAD selection in conjunction with the guidelines described above allows a conversion speed of 200 kps. See [Example 16-1](#) for code example.

16.8 A/D Acquisition Requirements

The analog input model of the 12-bit ADC is shown in [Figure 16-3](#). The total sampling time for the A/D is a function of the internal amplifier settling time and the holding capacitor charge time.

For the ADC to meet its specified accuracy, the charge holding capacitor (CHOLD) must be allowed to fully charge to the voltage level on the analog input pin. The source impedance (Rs), the interconnect impedance (RIC) and the internal sampling switch (RSS) impedance combine to directly affect the time required to charge the capacitor CHOLD. The combined impedance of the analog sources must therefore be small enough to fully charge the holding capacitor within the chosen sample time. To minimize the effects of pin leakage currents on the accuracy of the ADC, the maximum recommended source impedance, Rs, is 2.5 kΩ. After the analog input channel is selected (changed), this sampling function must be completed prior to starting the conversion. The internal holding capacitor will be in a discharged state prior to each sample operation.

FIGURE 16-3: 12-BIT A/D CONVERTER ANALOG INPUT MODEL



16.9 Module Power-Down Modes

The module has two internal power modes.

When the ADON bit is '1', the module is in Active mode; it is fully powered and functional.

When ADON is '0', the module is in Off mode. The digital and analog portions of the circuit are disabled for maximum current savings.

In order to return to the Active mode from Off mode, the user must wait for the ADC circuitry to stabilize.

16.10 A/D Operation During CPU Sleep and Idle Modes

16.10.1 A/D OPERATION DURING CPU SLEEP MODE

When the device enters Sleep mode, all clock sources to the module are shut down and stay at logic '0'.

If Sleep occurs in the middle of a conversion, the conversion is aborted. The converter will not continue with a partially completed conversion on exit from Sleep mode.

Register contents are not affected by the device entering or leaving Sleep mode.

The ADC module can operate during Sleep mode if the A/D clock source is set to RC (ADRC = 1). When the RC clock source is selected, the ADC module waits one instruction cycle before starting the conversion. This allows the *SLEEP* instruction to be executed which eliminates all digital switching noise from the conversion. When the conversion is complete, the CONV bit will be cleared and the result loaded into the ADCBUF register.

If the A/D interrupt is enabled, the device will wake-up from Sleep. If the A/D interrupt is not enabled, the ADC module will then be turned off, although the ADON bit will remain set.

16.10.2 A/D OPERATION DURING CPU IDLE MODE

The ADSIDL bit selects if the module will stop on Idle or continue on Idle. If ADSIDL = 0, the module will continue operation on assertion of Idle mode. If ADSIDL = 1, the module will stop on Idle.

16.11 Effects of a Reset

A device Reset forces all registers to their Reset state. This forces the ADC module to be turned off, and any conversion and sampling sequence is aborted. The values that are in the ADCBUF registers are not modified. The A/D Result register will contain unknown data after a Power-on Reset.

16.12 Output Formats

The A/D result is 12 bits wide. The data buffer RAM is also 12 bits wide. The 12-bit data can be read in one of four different formats. The FORM<1:0> bits select the format. Each of the output formats translates to a 16-bit result on the data bus.

FIGURE 16-4: A/D OUTPUT DATA FORMATS

| | | | | | | | | | | | | | | | | | | | | | |
|-------------------|--|--|--|--|--|------------------|------------------|------------------|------------------|------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| RAM Contents: | | | | | | d11 | d10 | d09 | d08 | d07 | d06 | d05 | d04 | d03 | d02 | d01 | d00 | | | | |
| Read to Bus: | | | | | | | | | | | | | | | | | | | | | |
| Signed Fractional | | | | | | $\overline{d11}$ | d10 | d09 | d08 | d07 | d06 | d05 | d04 | d03 | d02 | d01 | d00 | 0 | 0 | 0 | 0 |
| Fractional | | | | | | d11 | d10 | d09 | d08 | d07 | d06 | d05 | d04 | d03 | d02 | d01 | d00 | 0 | 0 | 0 | 0 |
| Signed Integer | | | | | | $\overline{d11}$ | $\overline{d11}$ | $\overline{d11}$ | $\overline{d11}$ | $\overline{d11}$ | d10 | d09 | d08 | d07 | d06 | d05 | d04 | d03 | d02 | d01 | d00 |
| Integer | | | | | | 0 | 0 | 0 | 0 | d11 | d10 | d09 | d08 | d07 | d06 | d05 | d04 | d03 | d02 | d01 | d00 |

16.13 Configuring Analog Port Pins

The use of the ADPCFG and TRIS registers control the operation of the A/D port pins. The port pins that are desired as analog inputs must have their corresponding TRIS bit set (input). If the TRIS bit is cleared (output), the digital output level (VOH or VOL) will be converted.

The A/D operation is independent of the state of the CH0SA<3:0>/CH0SB<3:0> bits and the TRIS bits.

When reading the PORT register, all pins configured as analog input channels will read as cleared.

Pins configured as digital inputs will not convert an analog input. Analog levels on any pin that is defined as a digital input (including the ANx pins) may cause the input buffer to consume current that exceeds the device specifications.

16.14 Connection Considerations

The analog inputs have diodes to VDD and VSS as ESD protection. This requires that the analog input be between VDD and VSS. If the input voltage exceeds this range by greater than 0.3V (either direction), one of the diodes becomes forward biased and it may damage the device if the input current specification is exceeded.

An external RC filter is sometimes added for anti-aliasing of the input signal. The R component should be selected to ensure that the sampling time requirements are satisfied. Any external components connected (via high-impedance) to an analog input pin (capacitor, zener diode, etc.) should have very little leakage current at the pin.

TABLE 16-2: A/D CONVERTER REGISTER MAP FOR dsPIC30F2011/3012

| SFR Name | Addr. | Bit 15 | Bit 14 | Bit 13 | Bit 12 | Bit 11 | Bit 10 | Bit 9 | Bit 8 | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Reset State |
|----------|-------|-----------|--------|--------|-----------|--------------------|--------|-----------|-------|-----------|-------|-----------|-------|------------|-------|-------|-------|---------------------|
| ADCBUF0 | 0280 | — | — | — | — | ADC Data Buffer 0 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCBUF1 | 0282 | — | — | — | — | ADC Data Buffer 1 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCBUF2 | 0284 | — | — | — | — | ADC Data Buffer 2 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCBUF3 | 0286 | — | — | — | — | ADC Data Buffer 3 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCBUF4 | 0288 | — | — | — | — | ADC Data Buffer 4 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCBUF5 | 028A | — | — | — | — | ADC Data Buffer 5 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCBUF6 | 028C | — | — | — | — | ADC Data Buffer 6 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCBUF7 | 028E | — | — | — | — | ADC Data Buffer 7 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCBUF8 | 0290 | — | — | — | — | ADC Data Buffer 8 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCBUF9 | 0292 | — | — | — | — | ADC Data Buffer 9 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCBUFA | 0294 | — | — | — | — | ADC Data Buffer 10 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCBUFB | 0296 | — | — | — | — | ADC Data Buffer 11 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCBUFC | 0298 | — | — | — | — | ADC Data Buffer 12 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCBUFD | 029A | — | — | — | — | ADC Data Buffer 13 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCBUFE | 029C | — | — | — | — | ADC Data Buffer 14 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCBUFF | 029E | — | — | — | — | ADC Data Buffer 15 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCON1 | 02A0 | ADON | — | ADSIDL | — | — | — | FORM<1:0> | | SSRC<2:0> | | | — | — | ASAM | SAMP | DONE | 0000 0000 0000 0000 |
| ADCON2 | 02A2 | VCFG<2:0> | | | — | — | CSCNA | — | — | BUFS | — | SMPI<3:0> | | | | BUFM | ALTS | 0000 0000 0000 0000 |
| ADCON3 | 02A4 | — | — | — | SAMC<4:0> | | | | | ADRC | — | ADCS<5:0> | | | | | | 0000 0000 0000 0000 |
| ADCHS | 02A6 | — | — | — | CH0NB | CH0SB<3:0> | | | | — | — | — | CH0NA | CH0SA<3:0> | | | | 0000 0000 0000 0000 |
| ADPCFG | 02A8 | — | — | — | — | — | — | — | — | PCFG7 | PCFG6 | PCFG5 | PCFG4 | PCFG3 | PCFG2 | PCFG1 | PCFG0 | 0000 0000 0000 0000 |
| ADCSSL | 02AA | — | — | — | — | — | — | — | — | CSSL7 | CSSL6 | CSSL5 | CSSL4 | CSSL3 | CSSL2 | CSSL1 | CSSL0 | 0000 0000 0000 0000 |

Legend: u = uninitialized bit; — = unimplemented bit, read as '0'

Note: Refer to the “dsPIC30F Family Reference Manual” (DS70046) for descriptions of register bit fields.

TABLE 16-3: A/D CONVERTER REGISTER MAP FOR dsPIC30F2012/3013

| SFR Name | Addr. | Bit 15 | Bit 14 | Bit 13 | Bit 12 | Bit 11 | Bit 10 | Bit 9 | Bit 8 | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Reset State |
|----------|-------|-----------|--------|--------|-----------|--------------------|--------|-----------|-------|-----------|-------|-----------|-------|------------|-------|-------|-------|---------------------|
| ADCBUF0 | 0280 | — | — | — | — | ADC Data Buffer 0 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCBUF1 | 0282 | — | — | — | — | ADC Data Buffer 1 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCBUF2 | 0284 | — | — | — | — | ADC Data Buffer 2 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCBUF3 | 0286 | — | — | — | — | ADC Data Buffer 3 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCBUF4 | 0288 | — | — | — | — | ADC Data Buffer 4 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCBUF5 | 028A | — | — | — | — | ADC Data Buffer 5 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCBUF6 | 028C | — | — | — | — | ADC Data Buffer 6 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCBUF7 | 028E | — | — | — | — | ADC Data Buffer 7 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCBUF8 | 0290 | — | — | — | — | ADC Data Buffer 8 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCBUF9 | 0292 | — | — | — | — | ADC Data Buffer 9 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCBUFA | 0294 | — | — | — | — | ADC Data Buffer 10 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCBUFB | 0296 | — | — | — | — | ADC Data Buffer 11 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCBUFC | 0298 | — | — | — | — | ADC Data Buffer 12 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCBUFD | 029A | — | — | — | — | ADC Data Buffer 13 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCBUFE | 029C | — | — | — | — | ADC Data Buffer 14 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCBUFF | 029E | — | — | — | — | ADC Data Buffer 15 | | | | | | | | | | | | 0000 uuuu uuuu uuuu |
| ADCON1 | 02A0 | ADON | — | ADSIDL | — | — | — | FORM<1:0> | | SSRC<2:0> | | | — | — | ASAM | SAMP | DONE | 0000 0000 0000 0000 |
| ADCON2 | 02A2 | VCFG<2:0> | | | — | — | CSCNA | — | — | BUFS | — | SMPI<3:0> | | | | BUFM | ALTS | 0000 0000 0000 0000 |
| ADCON3 | 02A4 | — | — | — | SAMC<4:0> | | | | | ADRC | — | ADCS<5:0> | | | | | | 0000 0000 0000 0000 |
| ADCHS | 02A6 | — | — | — | CH0NB | CH0SB<3:0> | | | | — | — | — | CH0NA | CH0SA<3:0> | | | | 0000 0000 0000 0000 |
| ADPCFG | 02A8 | — | — | — | — | — | — | PCFG9 | PCFG8 | PCFG7 | PCFG6 | PCFG5 | PCFG4 | PCFG3 | PCFG2 | PCFG1 | PCFG0 | 0000 0000 0000 0000 |
| ADCSSL | 02AA | — | — | — | — | — | — | CSSL9 | CSSL8 | CSSL7 | CSSL6 | CSSL5 | CSSL4 | CSSL3 | CSSL2 | CSSL1 | CSSL0 | 0000 0000 0000 0000 |

Legend: u = uninitialized bit; — = unimplemented bit, read as '0'

Note: Refer to the “dsPIC30F Family Reference Manual” (DS70046) for descriptions of register bit fields.

NOTES:

17.0 SYSTEM INTEGRATION

Note: This data sheet summarizes features of this group of dsPIC30F devices and is not intended to be a complete reference source. For more information on the CPU, peripherals, register descriptions and general device functionality, refer to the “*dsPIC30F Family Reference Manual*” (DS70046). For more information on the device instruction set and programming, refer to the “*16-bit MCU and DSC Programmer’s Reference Manual*” (DS70157).

There are several features intended to maximize system reliability, minimize cost through elimination of external components, provide Power Saving Operating modes and offer code protection:

- Oscillator Selection
- Reset
 - Power-on Reset (POR)
 - Power-up Timer (PWRT)
 - Oscillator Start-up Timer (OST)
 - Programmable Brown-out Reset (BOR)
- Watchdog Timer (WDT)
- Low-Voltage Detect
- Power-Saving Modes (Sleep and Idle)
- Code Protection
- Unit ID Locations
- In-Circuit Serial Programming (ICSP)

dsPIC30F devices have a Watchdog Timer which is permanently enabled via the Configuration bits or can be software controlled. It runs off its own RC oscillator for added reliability. There are two timers that offer necessary delays on power-up. One is the Oscillator Start-up Timer (OST), intended to keep the chip in Reset until the crystal oscillator is stable. The other is the Power-up Timer (PWRT) which provides a delay on power-up only, designed to keep the part in Reset while the power supply stabilizes. With these two timers on-chip, most applications need no external Reset circuitry.

Sleep mode is designed to offer a very low current Power-Down mode. The user can wake-up from Sleep through external Reset, Watchdog Timer Wake-up, or through an interrupt. Several oscillator options are also made available to allow the part to fit a wide variety of applications. In the Idle mode, the clock sources are still active but the CPU is shut-off. The RC oscillator option saves system cost while the LP crystal option saves power.

17.1 Oscillator System Overview

The dsPIC30F oscillator system has the following modules and features:

- Various external and internal oscillator options as clock sources
- An on-chip PLL to boost internal operating frequency
- A clock switching mechanism between various clock sources
- Programmable clock postscaler for system power savings
- A Fail-Safe Clock Monitor (FSCM) that detects clock failure and takes fail-safe measures
- Clock Control register (OSCCON)
- Configuration bits for main oscillator selection

Configuration bits determine the clock source upon Power-on Reset (POR) and Brown-out Reset (BOR). Thereafter, the clock source can be changed between permissible clock sources. The OSCCON register controls the clock switching and reflects system clock related status bits.

[Table 17-1](#) provides a summary of the dsPIC30F Oscillator Operating modes. A simplified diagram of the oscillator system is shown in [Figure 17-1](#).

dsPIC30F2011/2012/3012/3013

TABLE 17-1: OSCILLATOR OPERATING MODES

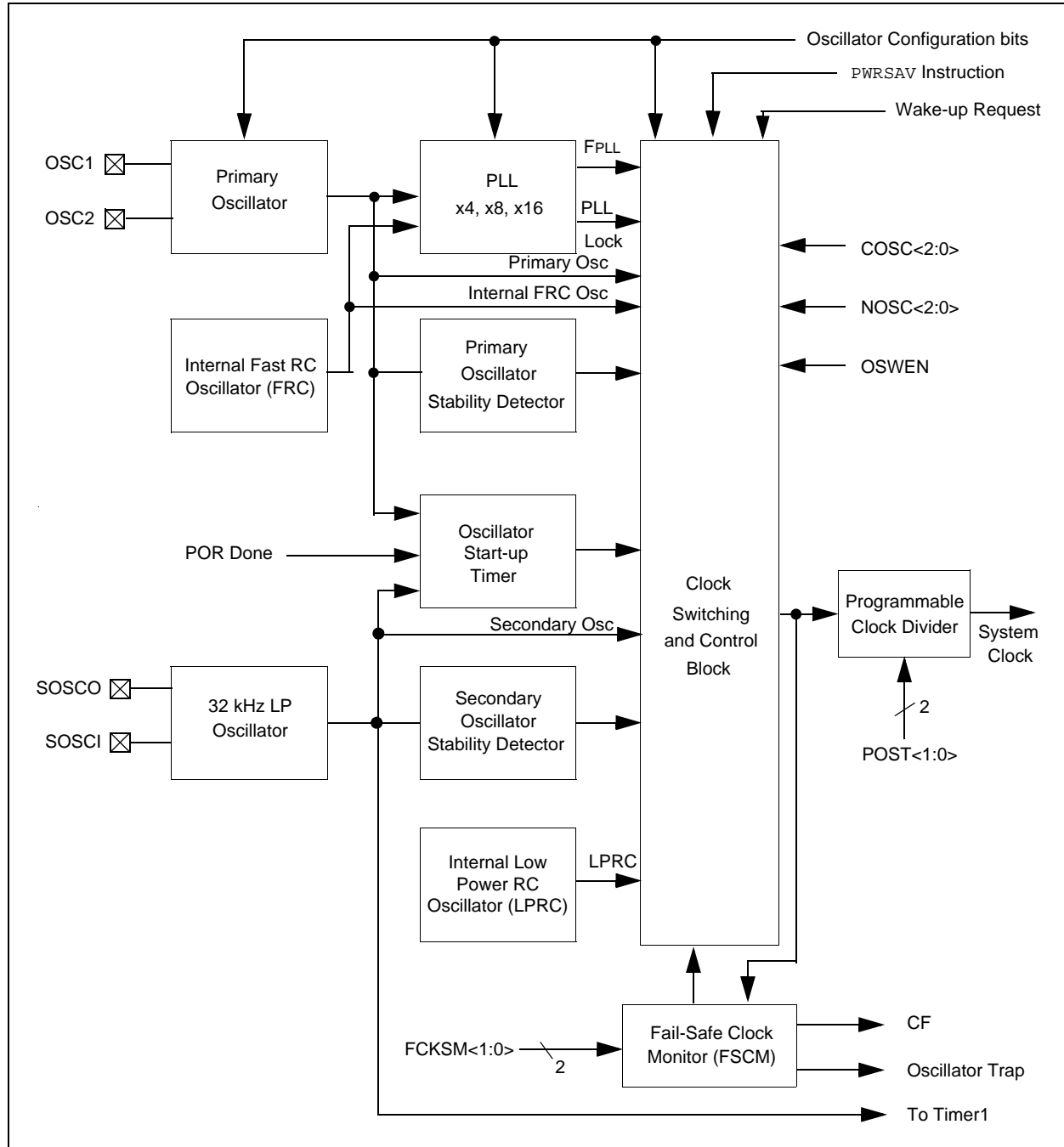
| Oscillator Mode | Description |
|-----------------|---|
| XTL | 200 kHz-4 MHz crystal on OSC1:OSC2. |
| XT | 4 MHz-10 MHz crystal on OSC1:OSC2. |
| XT w/PLL 4x | 4 MHz-10 MHz crystal on OSC1:OSC2, 4x PLL enabled. |
| XT w/PLL 8x | 4 MHz-10 MHz crystal on OSC1:OSC2, 8x PLL enabled. |
| XT w/PLL 16x | 4 MHz-7.5 MHz crystal on OSC1:OSC2, 16x PLL enabled ⁽¹⁾ . |
| LP | 32 kHz crystal on SOSCO:SOSCI ⁽²⁾ . |
| HS | 10 MHz-25 MHz crystal. |
| HS/2 w/PLL 4x | 10 MHz-20 MHz crystal, divide by 2, 4x PLL enabled. |
| HS/2 w/PLL 8x | 10 MHz-20 MHz crystal, divide by 2, 8x PLL enabled. |
| HS/2 w/PLL 16x | 10 MHz-15 MHz crystal, divide by 2, 16x PLL enabled ⁽¹⁾ . |
| HS/3 w/PLL 4x | 12 MHz-25 MHz crystal, divide by 3, 4x PLL enabled. |
| HS/3 w/PLL 8x | 12 MHz-25 MHz crystal, divide by 3, 8x PLL enabled. |
| HS/3 w/PLL 16x | 12 MHz-22.5 MHz crystal, divide by 3, 16x PLL enabled ⁽¹⁾ . |
| EC | External clock input (0-40 MHz). |
| ECIO | External clock input (0-40 MHz), OSC2 pin is I/O. |
| EC w/PLL 4x | External clock input (4-10 MHz), OSC2 pin is I/O, 4x PLL enabled. |
| EC w/PLL 8x | External clock input (4-10 MHz), OSC2 pin is I/O, 8x PLL enabled. |
| EC w/PLL 16x | External clock input (4-7.5 MHz), OSC2 pin is I/O, 16x PLL enabled ⁽¹⁾ . |
| ERC | External RC oscillator, OSC2 pin is Fosc/4 output ⁽³⁾ . |
| ERCIO | External RC oscillator, OSC2 pin is I/O ⁽³⁾ . |
| FRC | 7.37 MHz internal RC oscillator. |
| FRC w/PLL 4x | 7.37 MHz Internal RC oscillator, 4x PLL enabled. |
| FRC w/PLL 8x | 7.37 MHz Internal RC oscillator, 8x PLL enabled. |
| FRC w/PLL 16x | 7.37 MHz Internal RC oscillator, 16x PLL enabled. |
| LPRC | 512 kHz internal RC oscillator. |

Note 1: dsPIC30F maximum operating frequency of 120 MHz must be met.

2: LP oscillator can be conveniently shared as system clock, as well as real-time clock for Timer1.

3: Requires external R and C. Frequency operation up to 4 MHz.

FIGURE 17-1: OSCILLATOR SYSTEM BLOCK DIAGRAM



dsPIC30F2011/2012/3012/3013

17.2 Oscillator Configurations

17.2.1 INITIAL CLOCK SOURCE SELECTION

While coming out of Power-on Reset or Brown-out Reset, the device selects its clock source based on:

- FOS<2:0> Configuration bits that select one of four oscillator groups,
- and FPR<4:0> Configuration bits that select one of 15 oscillator choices within the primary group.

The selection is as shown in [Table 17-2](#).

17.2.2 OSCILLATOR START-UP TIMER (OST)

In order to ensure that a crystal oscillator (or ceramic resonator) has started and stabilized, an Oscillator Start-up Timer is included. It is a simple 10-bit counter that counts 1024 TOSC cycles before releasing the oscillator clock to the rest of the system. The time-out period is designated as TOST.

The TOST time is involved every time the oscillator has to restart (i.e., on POR, BOR and wake-up from Sleep). The Oscillator Start-up Timer is applied to the LP oscillator, XT, XTL and HS modes (upon wake-up from Sleep, POR and BOR) for the primary oscillator.

TABLE 17-2: CONFIGURATION BIT VALUES FOR CLOCK SELECTION

| Oscillator Mode | Oscillator Source | FOS<2:0> | | | FPR<4:0> | | | | | OSC2 Function |
|-----------------|-------------------|----------|---|---|----------|---|---|---|---|---------------|
| ECIO w/PLL 4x | PLL | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | I/O |
| ECIO w/PLL 8x | PLL | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | I/O |
| ECIO w/PLL 16x | PLL | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | I/O |
| FRC w/PLL 4X | PLL | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | I/O |
| FRC w/PLL 8x | PLL | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | I/O |
| FRC w/PLL 16x | PLL | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | I/O |
| XT w/PLL 4x | PLL | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | OSC2 |
| XT w/PLL 8x | PLL | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | OSC2 |
| XT w/PLL 16x | PLL | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | OSC2 |
| HS2 w/PLL 4x | PLL | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | OSC2 |
| HS2 w/PLL 8x | PLL | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | OSC2 |
| HS2 w/ PLL 16x | PLL | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | OSC2 |
| HS3 w/PLL 4x | PLL | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | OSC2 |
| HS3 w/PLL 8x | PLL | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | OSC2 |
| HS3 w/PLL 16x | PLL | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | OSC2 |
| ECIO | External | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | I/O |
| XT | External | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | OSC2 |
| HS | External | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | OSC2 |
| EC | External | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | CLKO |
| ERC | External | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | CLKO |
| ERCIO | External | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | I/O |
| XTL | External | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | OSC2 |
| LP | Secondary | 0 | 0 | 0 | X | X | X | X | X | (Note 1, 2) |
| FRC | Internal FRC | 0 | 0 | 1 | X | X | X | X | X | (Note 1, 2) |
| LPRC | Internal LPRC | 0 | 1 | 0 | X | X | X | X | X | (Note 1, 2) |

Note 1: The OSC2 pin is either usable as a general purpose I/O pin or is completely unusable, depending on the Primary Oscillator mode selection (FPR<4:0>).

- 2:** OSC1 pin cannot be used as an I/O pin even if the secondary oscillator or an internal clock source is selected at all times.

17.2.3 LP OSCILLATOR CONTROL

Enabling the LP oscillator is controlled with two elements:

- The current oscillator group bits COSC<2:0>.
- The LPOSCEN bit (OSCCON register).

The LP oscillator is on (even during Sleep mode) if LPOSCEN = 1. The LP oscillator is the device clock if:

- COSC<2:0> = 000 (LP selected as main osc.) and
- LPOSCEN = 1

Keeping the LP oscillator on at all times allows for a fast switch to the 32 kHz system clock for lower power operation. Returning to the faster main oscillator will still require a start-up time

17.2.4 PHASE LOCKED LOOP (PLL)

The PLL multiplies the clock which is generated by the primary oscillator or Fast RC oscillator. The PLL is selectable to have either gains of x4, x8, and x16. Input and output frequency ranges are summarized in [Table 17-3](#).

TABLE 17-3: PLL FREQUENCY RANGE

| F _{IN} | PLL Multiplier | F _{OUT} |
|-----------------|----------------|------------------|
| 4 MHz-10 MHz | x4 | 16 MHz-40 MHz |
| 4 MHz-10 MHz | x8 | 32 MHz-80 MHz |
| 4 MHz-7.5 MHz | x16 | 64 MHz-120 MHz |

The PLL features a lock output which is asserted when the PLL enters a phase locked state. Should the loop fall out of lock (e.g., due to noise), the lock signal will be rescinded. The state of this signal is reflected in the read-only LOCK bit in the OSCCON register.

17.2.5 FAST RC OSCILLATOR (FRC)

The FRC oscillator is a fast (7.37 MHz \pm 2% nominal) internal RC oscillator. This oscillator is intended to provide reasonable device operating speeds without the use of an external crystal, ceramic resonator, or RC network. The FRC oscillator can be used with the PLL to obtain higher clock frequencies.

The dsPIC30F operates from the FRC oscillator whenever the current oscillator selection control bits in the OSCCON register (OSCCON<14:12>) are set to '001'.

The four bit field specified by TUN<3:0> (OSCTUN<3:0>) allows the user to tune the internal fast RC oscillator (nominal 7.37 MHz). The user can tune the FRC oscillator within a range of +10.5% (840 kHz) and -12% (960 kHz) in steps of 1.50% around the factory calibrated setting, as shown in [Table 17-4](#).

Note: OSCTUN functionality has been provided to help customers compensate for temperature effects on the FRC frequency over a wide range of temperatures. The tuning step size is an approximation and is neither characterized nor tested.

If OSCCON<14:12> are set to '111' and FPR<4:0> are set to '00001', '01010' or '00011', a PLL multiplier of 4, 8 or 16 (respectively) is applied.

Note: When a 16x PLL is used, the FRC frequency must not be tuned to a frequency greater than 7.5 MHz.

TABLE 17-4: FRC TUNING

| TUN<3:0> Bits | FRC Frequency |
|---------------|--|
| 0111 | + 10.5% |
| 0110 | + 9.0% |
| 0101 | + 7.5% |
| 0100 | + 6.0% |
| 0011 | + 4.5% |
| 0010 | + 3.0% |
| 0001 | + 1.5% |
| 0000 | Center Frequency (oscillator is running at calibrated frequency) |
| 1111 | - 1.5% |
| 1110 | - 3.0% |
| 1101 | - 4.5% |
| 1100 | - 6.0% |
| 1011 | - 7.5% |
| 1010 | - 9.0% |
| 1001 | - 10.5% |
| 1000 | - 12.0% |

17.2.6 LOW-POWER RC OSCILLATOR (LPRC)

The LPRC oscillator is a component of the Watchdog Timer (WDT) and oscillates at a nominal frequency of 512 kHz. The LPRC oscillator is the clock source for the Power-up Timer (PWRT) circuit, WDT and clock monitor circuits. It may also be used to provide a low-frequency clock source option for applications where power consumption is critical and timing accuracy is not required.

The LPRC oscillator is always enabled at a Power-on Reset because it is the clock source for the PWRT. After the PWRT expires, the LPRC oscillator will remain on if one of the following is true:

- The Fail-Safe Clock Monitor is enabled
- The WDT is enabled
- The LPRC oscillator is selected as the system clock via the COSC<2:0> control bits in the OSCCON register

If one of the above conditions is not true, the LPRC will shut-off after the PWRT expires.

Note 1: OSC2 pin function is determined by the Primary Oscillator mode selection (FPR<4:0>).

2: OSC1 pin cannot be used as an I/O pin even if the secondary oscillator or an internal clock source is selected at all times.

17.2.7 FAIL-SAFE CLOCK MONITOR

The Fail-Safe Clock Monitor (FSCM) allows the device to continue to operate even in the event of an oscillator failure. The FSCM function is enabled by appropriately programming the FCKSM Configuration bits (clock switch and monitor selection bits) in the FOSC Device Configuration register. If the FSCM function is enabled, the LPRC internal oscillator will run at all times (except during Sleep mode) and will not be subject to control by the SWDTEN bit.

In the event of an oscillator failure, the FSCM will generate a clock failure trap event and will switch the system clock over to the FRC oscillator. The user will then have the option to either attempt to restart the oscillator or execute a controlled shutdown. The user may decide to treat the trap as a warm Reset by simply loading the Reset address into the oscillator fail trap vector. In this event, the CF (Clock Fail) bit (OSCCON<3>) is also set whenever a clock failure is recognized.

In the event of a clock failure, the WDT is unaffected and continues to run on the LPRC clock.

If the oscillator has a very slow start-up time coming out of POR, BOR or Sleep, it is possible that the PWRT timer will expire before the oscillator has started. In such cases, the FSCM will be activated and the FSCM will initiate a clock failure trap, and the COSC<2:0> bits are loaded with FRC oscillator selection. This will effectively shut-off the original oscillator that was trying to start.

The user may detect this situation and restart the oscillator in the clock fail trap ISR.

Upon a clock failure detection, the FSCM module will initiate a clock switch to the FRC oscillator as follows:

1. The COSC bits (OSCCON<14:12>) are loaded with the FRC oscillator selection value.
2. CF bit is set (OSCCON<3>).
3. OSWEN control bit (OSCCON<0>) is cleared.

For the purpose of clock switching, the clock sources are sectioned into four groups:

- Primary (with or without PLL)
- Secondary
- Internal FRC
- Internal LPRC

The user can switch between these functional groups but cannot switch between options within a group. If the primary group is selected, then the choice within the group is always determined by the FPR<4:0> Configuration bits.

The OSCCON register holds the Control and Status bits related to clock switching.

- COSC<2:0>: Read-only bits always reflect the current oscillator group in effect.
- NOSC<2:0>: Control bits which are written to indicate the new oscillator group of choice.
 - On POR and BOR, COSC<2:0> and NOSC<2:0> are both loaded with the Configuration bit values FOS<2:0>.
- LOCK: The LOCK bit indicates a PLL lock.
- CF: Read-only bit indicating if a clock fail detect has occurred.
- OSWEN: Control bit changes from a '0' to a '1' when a clock transition sequence is initiated. Clearing the OSWEN control bit will abort a clock transition in progress (used for hang-up situations).

If Configuration bits FCKSM<1:0> = 1x, then the clock switching and Fail-Safe Clock monitoring functions are disabled. This is the default Configuration bit setting.

If clock switching is disabled, then the FOS<2:0> and FPR<4:0> bits directly control the oscillator selection and the COSC<2:0> bits do not control the clock selection. However, these bits will reflect the clock source selection.

Note: The application should not attempt to switch to a clock of frequency lower than 100 kHz when the Fail-Safe Clock Monitor is enabled. If such clock switching is performed, the device may generate an oscillator fail trap and switch to the Fast RC oscillator.

17.2.8 PROTECTION AGAINST ACCIDENTAL WRITES TO OSCCON

A write to the OSCCON register is intentionally made difficult because it controls clock switching and clock scaling.

To write to the OSCCON low byte, the following code sequence must be executed without any other instructions in between:

```
Byte Write 0x46 to OSCCON low
Byte Write 0x57 to OSCCON low
```

Byte write is allowed for one instruction cycle. Write the desired value or use bit manipulation instruction.

To write to the OSCCON high byte, the following instructions must be executed without any other instructions in between:

```
Byte Write 0x78 to OSCCON high
Byte Write 0x9A to OSCCON high
```

Byte write is allowed for one instruction cycle. Write the desired value or use bit manipulation instruction.

17.3 Reset

The dsPIC30F2011/2012/3012/3013 devices differentiate between various kinds of Reset:

- Power-on Reset (POR)
- $\overline{\text{MCLR}}$ Reset during normal operation
- $\overline{\text{MCLR}}$ Reset during Sleep
- Watchdog Timer (WDT) Reset (during normal operation)
- Programmable Brown-out Reset (BOR)
- RESET Instruction
- Reset caused by trap lockup (TRAPR)
- Reset caused by illegal opcode or by using an uninitialized W register as an address pointer (IOPUWR)

Different registers are affected in different ways by various Reset conditions. Most registers are not affected by a WDT wake-up since this is viewed as the resumption of normal operation. Status bits from the RCON register are set or cleared differently in different Reset situations, as indicated in Table 17-5. These bits are used in software to determine the nature of the Reset.

A block diagram of the On-Chip Reset Circuit is shown in Figure 17-2.

A $\overline{\text{MCLR}}$ noise filter is provided in the $\overline{\text{MCLR}}$ Reset path. The filter detects and ignores small pulses.

Internally generated Resets do not drive $\overline{\text{MCLR}}$ pin low.

17.3.1 POR: POWER-ON RESET

A power-on event will generate an internal POR pulse when a VDD rise is detected. The Reset pulse will occur at the POR circuit threshold voltage (VPOR) which is nominally 1.85V. The device supply voltage characteristics must meet specified starting voltage and rise rate requirements. The POR pulse will reset a POR timer and place the device in the Reset state. The POR also selects the device clock source identified by the oscillator configuration fuses.

The POR circuit inserts a small delay, TPOR, which is nominally 10 μs and ensures that the device bias circuits are stable. Furthermore, a user selected power-up time-out (TPWRT) is applied. The TPWRT parameter is based on device Configuration bits and can be 0 ms (no delay), 4 ms, 16 ms or 64 ms. The total delay is at device power-up, TPOR + TPWRT. When these delays have expired, $\overline{\text{SYSRST}}$ will be negated on the next leading edge of the Q1 clock and the PC will jump to the Reset vector.

The timing for the $\overline{\text{SYSRST}}$ signal is shown in Figure 17-3 through Figure 17-5.

FIGURE 17-2: RESET SYSTEM BLOCK DIAGRAM

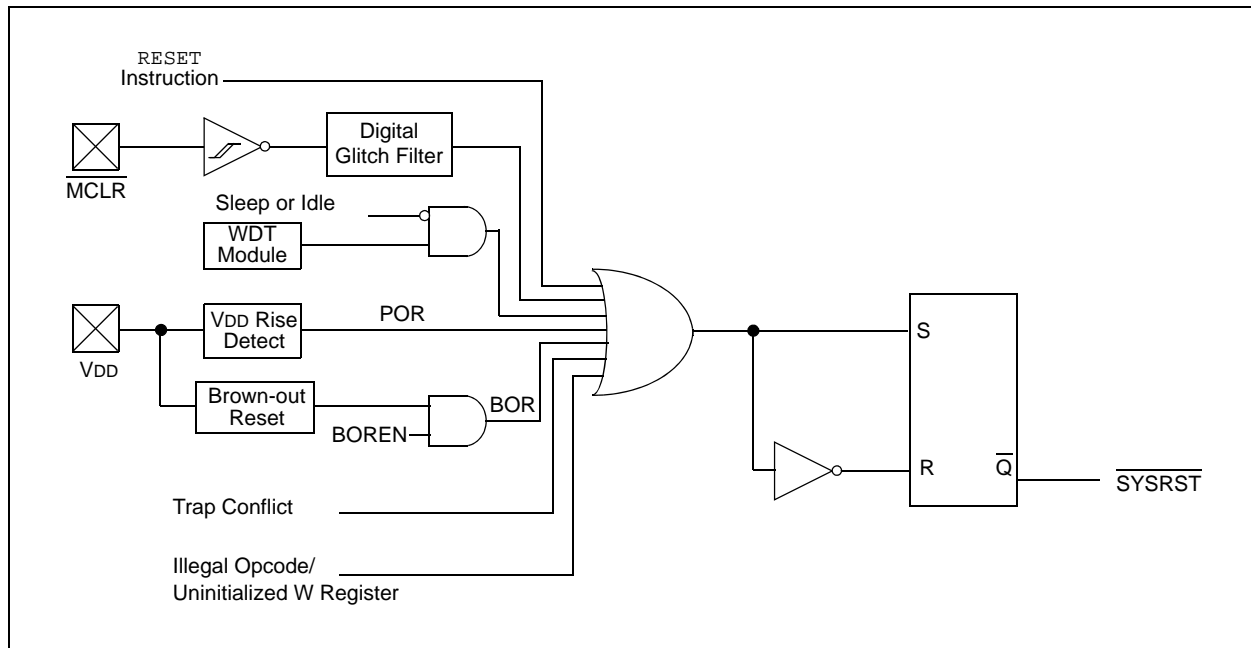


FIGURE 17-3: TIME-OUT SEQUENCE ON POWER-UP ($\overline{\text{MCLR}}$ TIED TO V_{DD})

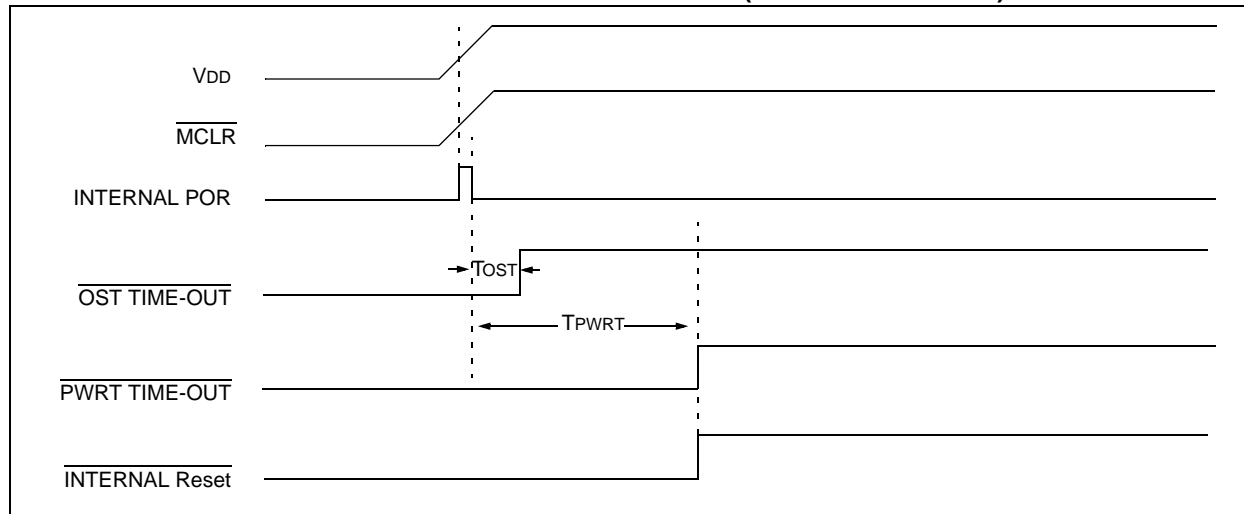


FIGURE 17-4: TIME-OUT SEQUENCE ON POWER-UP ($\overline{\text{MCLR}}$ NOT TIED TO V_{DD}): CASE 1

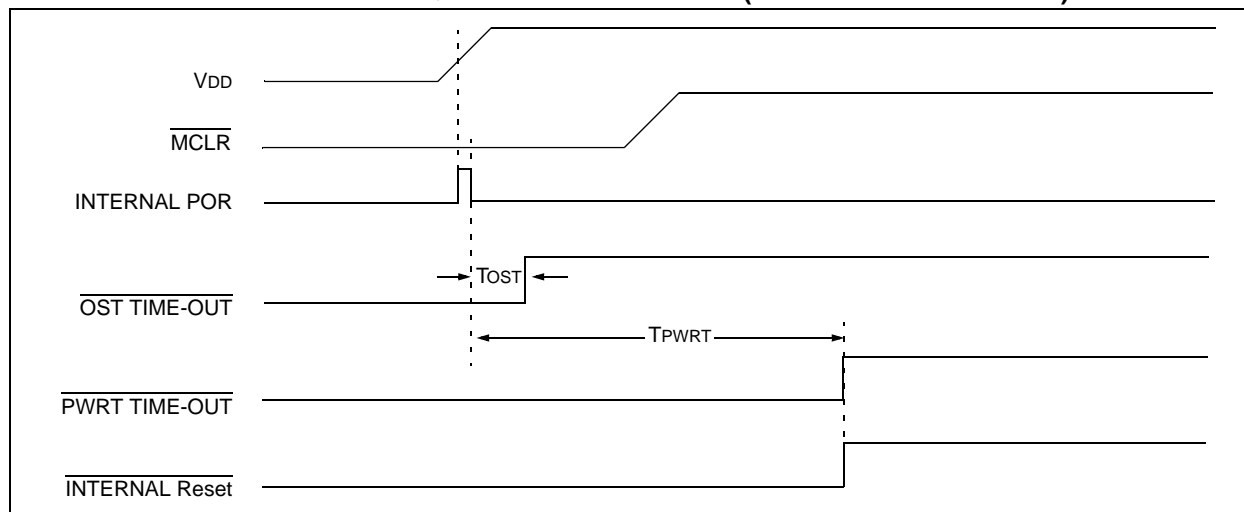
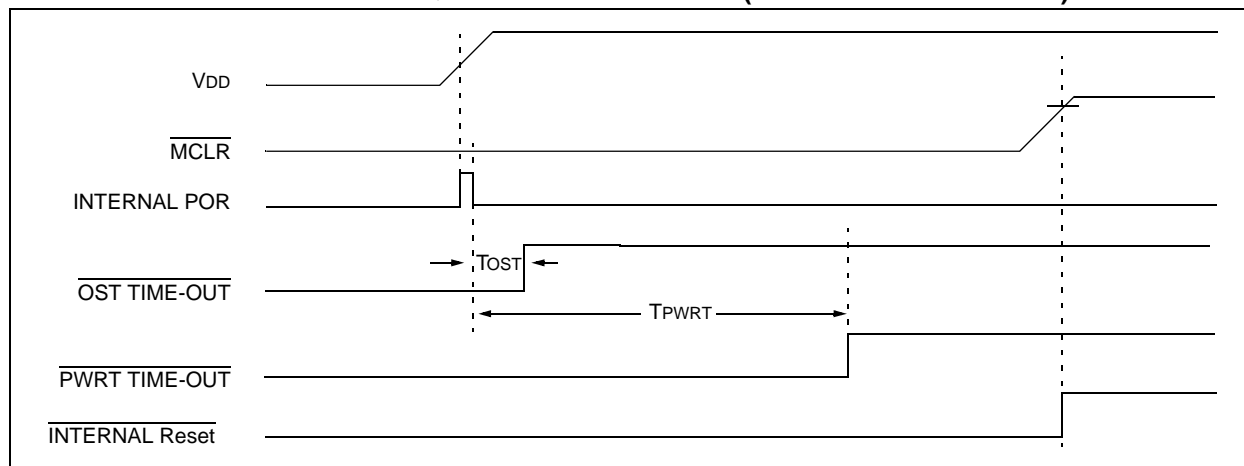


FIGURE 17-5: TIME-OUT SEQUENCE ON POWER-UP ($\overline{\text{MCLR}}$ NOT TIED TO V_{DD}): CASE 2



17.3.1.1 POR with Long Crystal Start-up Time (with FSCM Enabled)

The oscillator start-up circuitry is not linked to the POR circuitry. Some crystal circuits (especially low frequency crystals) will have a relatively long start-up time. Therefore, one or more of the following conditions is possible after the POR timer and the PWRT have expired:

- The oscillator circuit has not begun to oscillate.
- The Oscillator Start-up Timer has not expired (if a crystal oscillator is used).
- The PLL has not achieved a LOCK (if PLL is used).

If the FSCM is enabled and one of the above conditions is true, then a clock failure trap will occur. The device will automatically switch to the FRC oscillator and the user can switch to the desired crystal oscillator in the trap ISR.

17.3.1.2 Operating without FSCM and PWRT

If the FSCM is disabled and the Power-up Timer (PWRT) is also disabled, then the device will exit rapidly from Reset on power-up. If the clock source is FRC, LPRC, ERC or EC, it will be active immediately.

If the FSCM is disabled and the system clock has not started, the device will be in a frozen state at the Reset vector until the system clock starts. From the user's perspective, the device will appear to be in Reset until a system clock is available.

17.3.2 BOR: PROGRAMMABLE BROWN-OUT RESET

The BOR (Brown-out Reset) module is based on an internal voltage reference circuit. The main purpose of the BOR module is to generate a device Reset when a brown-out condition occurs. Brown-out conditions are generally caused by glitches on the AC mains (i.e., missing portions of the AC cycle waveform due to bad power transmission lines, or voltage sags due to excessive current draw when a large inductive load is turned on).

The BOR module allows selection of one of the following voltage trip points (see Table 20-11):

- 2.6V-2.71V
- 4.1V-4.4V
- 4.58V-4.73V

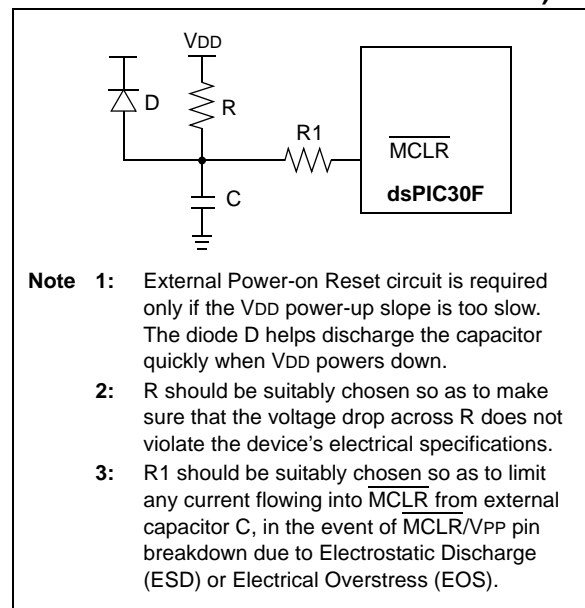
Note: The BOR voltage trip points indicated here are nominal values provided for design guidance only. Refer to the Electrical Specifications in the specific device data sheet for BOR voltage limit specifications.

A BOR will generate a Reset pulse which will reset the device. The BOR will select the clock source based on the device Configuration bit values (FOS<2:0> and FPR<4:0>). Furthermore, if an Oscillator mode is selected, the BOR will activate the Oscillator Start-up Timer (OST). The system clock is held until OST expires. If the PLL is used, then the clock will be held until the LOCK bit (OSCCON<5>) is '1'.

Concurrently, the POR time-out (TPOR) and the PWRT time-out (TPWRT) will be applied before the internal Reset is released. If TPWRT = 0 and a crystal oscillator is being used, then a nominal delay of TFSCM = 100 μ s is applied. The total delay in this case is (TPOR + TFSCM).

The BOR Status bit (RCON<1>) will be set to indicate that a BOR has occurred. The BOR circuit, if enabled, will continue to operate while in Sleep or Idle modes and will reset the device should VDD fall below the BOR threshold voltage.

FIGURE 17-6: EXTERNAL POWER-ON RESET CIRCUIT (FOR SLOW VDD POWER-UP)



Note: Dedicated supervisory devices, such as the MCP1XX and MCP8XX, may also be used as an external Power-on Reset circuit.

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Table 17-5 shows the Reset conditions for the RCON register. Since the control bits within the RCON register are R/W, the information in the table means that all the bits are negated prior to the action specified in the condition column.

TABLE 17-5: INITIALIZATION CONDITION FOR RCON REGISTER: CASE 1

| Condition | Program Counter | TRAPR | IOPUWR | EXTR | SWR | WDTO | IDLE | SLEEP | POR | BOR |
|--|-----------------------|-------|--------|------|-----|------|------|-------|-----|-----|
| Power-on Reset | 0x000000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| Brown-out Reset | 0x000000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| MCLR Reset during normal operation | 0x000000 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Software Reset during normal operation | 0x000000 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| MCLR Reset during Sleep | 0x000000 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| MCLR Reset during Idle | 0x000000 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| WDT Time-out Reset | 0x000000 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| WDT Wake-up | PC + 2 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| Interrupt Wake-up from Sleep | PC + 2 ⁽¹⁾ | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Clock Failure Trap | 0x000004 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Trap Reset | 0x000000 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Illegal Operation Trap | 0x000000 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Note 1: When the wake-up is due to an enabled interrupt, the PC is loaded with the corresponding interrupt vector.

Table 17-6 shows a second example of the bit conditions for the RCON register. In this case, it is not assumed the user has set/cleared specific bits prior to action specified in the condition column.

TABLE 17-6: INITIALIZATION CONDITION FOR RCON REGISTER: CASE 2

| Condition | Program Counter | TRAPR | IOPUWR | EXTR | SWR | WDTO | IDLE | SLEEP | POR | BOR |
|--|-----------------------|-------|--------|------|-----|------|------|-------|-----|-----|
| Power-on Reset | 0x000000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| Brown-out Reset | 0x000000 | u | u | u | u | u | u | u | 0 | 1 |
| MCLR Reset during normal operation | 0x000000 | u | u | 1 | 0 | 0 | 0 | 0 | u | u |
| Software Reset during normal operation | 0x000000 | u | u | 0 | 1 | 0 | 0 | 0 | u | u |
| MCLR Reset during Sleep | 0x000000 | u | u | 1 | u | 0 | 0 | 1 | u | u |
| MCLR Reset during Idle | 0x000000 | u | u | 1 | u | 0 | 1 | 0 | u | u |
| WDT Time-out Reset | 0x000000 | u | u | 0 | 0 | 1 | 0 | 0 | u | u |
| WDT Wake-up | PC + 2 | u | u | u | u | 1 | u | 1 | u | u |
| Interrupt Wake-up from Sleep | PC + 2 ⁽¹⁾ | u | u | u | u | u | u | 1 | u | u |
| Clock Failure Trap | 0x000004 | u | u | u | u | u | u | u | u | u |
| Trap Reset | 0x000000 | 1 | u | u | u | u | u | u | u | u |
| Illegal Operation Reset | 0x000000 | u | 1 | u | u | u | u | u | u | u |

Legend: u = unchanged

Note 1: When the wake-up is due to an enabled interrupt, the PC is loaded with the corresponding interrupt vector.

17.4 Watchdog Timer (WDT)

17.4.1 WATCHDOG TIMER OPERATION

The primary function of the Watchdog Timer (WDT) is to reset the processor in the event of a software malfunction. The WDT is a free-running timer which runs off an on-chip RC oscillator, requiring no external component. Therefore, the WDT timer will continue to operate even if the main processor clock (e.g., the crystal oscillator) fails.

17.4.2 ENABLING AND DISABLING THE WDT

The Watchdog Timer can be “Enabled” or “Disabled” only through a Configuration bit (FWDTEN) in the Configuration register, FWDTE.

Setting FWDTE = 1 enables the Watchdog Timer. The enabling is done when programming the device. By default, after chip erase, FWDTE bit = 1. Any device programmer capable of programming dsPIC30F devices allows programming of this and other Configuration bits.

If enabled, the WDT will increment until it overflows or “times out”. A WDT time-out will force a device Reset (except during Sleep). To prevent a WDT time-out, the user must clear the Watchdog Timer using a CLRWDTE instruction.

If a WDT times out during Sleep, the device will wake-up. The WDTO bit in the RCON register will be cleared to indicate a wake-up resulting from a WDT time-out.

Setting FWDTE = 0 allows user software to enable/disable the Watchdog Timer via the SWDTE (RCON<5>) control bit.

17.5 Low-Voltage Detect

The Low-Voltage Detect (LVD) module is used to detect when the VDD of the device drops below a threshold value, VLVD, which is determined by the LVDL<3:0> bits (RCON<11:8>) and is thus user programmable. The internal voltage reference circuitry requires a nominal amount of time to stabilize, and the BGST bit (RCON<13>) indicates when the voltage reference has stabilized.

In some devices, the LVD threshold voltage may be applied externally on the LVDIN pin.

The LVD module is enabled by setting the LVDEN bit (RCON<12>).

17.6 Power-Saving Modes

There are two power-saving states that can be entered through the execution of a special instruction, PWRSAV; these are Sleep and Idle.

The format of the PWRSAV instruction is as follows:

PWRSAV <parameter>, where ‘parameter’ defines Idle or Sleep mode.

17.6.1 SLEEP MODE

In Sleep mode, the clock to the CPU and peripherals is shut down. If an on-chip oscillator is being used, it is shut down.

The Fail-Safe Clock Monitor is not functional during Sleep since there is no clock to monitor. However, LPRC clock remains active if WDT is operational during Sleep.

The brown-out protection circuit and the Low-Voltage Detect circuit, if enabled, will remain functional during Sleep.

The processor wakes up from Sleep if at least one of the following conditions has occurred:

- any interrupt that is individually enabled and meets the required priority level
- any Reset (POR, BOR and MCLR)
- WDT time-out

On waking up from Sleep mode, the processor will restart the same clock that was active prior to entry into Sleep mode. When clock switching is enabled, bits COSC<2:0> will determine the oscillator source that will be used on wake-up. If clock switch is disabled, then there is only one system clock.

Note: If a POR or BOR occurred, the selection of the oscillator is based on the FOS<2:0> and FPR<4:0> Configuration bits.

If the clock source is an oscillator, the clock to the device will be held off until OST times out (indicating a stable oscillator). If PLL is used, the system clock is held off until LOCK = 1 (indicating that the PLL is stable). In either case, TPOR, TLOCK and TPWRT delays are applied.

If EC, FRC, LPRC or ERC oscillators are used, then a delay of TPOR (~ 10 μs) is applied. This is the smallest delay possible on wake-up from Sleep.

Moreover, if LP oscillator was active during Sleep and LP is the oscillator used on wake-up, then the start-up delay will be equal to TPOR. PWRT delay and OST timer delay are not applied. In order to have the smallest possible start-up delay when waking up from Sleep, one of these faster wake-up options should be selected before entering Sleep.

Any interrupt that is individually enabled (using the corresponding IE bit) and meets the prevailing priority level will be able to wake-up the processor. The processor will process the interrupt and branch to the ISR. The Sleep Status bit in the RCON register is set upon wake-up.

Note: In spite of various delays applied (TPOR, TLOCK and TPWRT), the crystal oscillator (and PLL) may not be active at the end of the time-out (e.g., for low-frequency crystals). In such cases, if FSCM is enabled, then the device will detect this as a clock failure and process the clock failure trap, the FRC oscillator will be enabled and the user will have to re-enable the crystal oscillator. If FSCM is not enabled, then the device will simply suspend execution of code until the clock is stable and will remain in Sleep until the oscillator clock has started.

All Resets will wake-up the processor from Sleep mode. Any Reset, other than POR, will set the Sleep Status bit. In a POR, the Sleep bit is cleared.

If the Watchdog Timer is enabled, then the processor will wake-up from Sleep mode upon WDT time-out. The Sleep and WDTO Status bits are both set.

17.6.2 IDLE MODE

In Idle mode, the clock to the CPU is shut down while peripherals keep running. Unlike Sleep mode, the clock source remains active.

Several peripherals have a control bit in each module that allows them to operate during Idle.

LPRC Fail-Safe Clock remains active if clock failure detect is enabled.

The processor wakes up from Idle if at least one of the following conditions has occurred:

- any interrupt that is individually enabled (IE bit is '1') and meets the required priority level
- any Reset (POR, BOR, MCLR)
- WDT time-out

Upon wake-up from Idle mode, the clock is re-applied to the CPU and instruction execution begins immediately, starting with the instruction following the PWRSAV instruction.

Any interrupt that is individually enabled (using IE bit) and meets the prevailing priority level will be able to wake-up the processor. The processor will process the interrupt and branch to the ISR. The Idle Status bit in the RCON register is set upon wake-up.

Any Reset other than POR will set the Idle Status bit. On a POR, the Idle bit is cleared.

If Watchdog Timer is enabled, then the processor will wake-up from Idle mode upon WDT time-out. The Idle and WDTO Status bits are both set.

Unlike wake-up from Sleep, there are no time delays involved in wake-up from Idle.

17.7 Device Configuration Registers

The Configuration bits in each device Configuration register specify some of the device modes and are programmed by a device programmer, or by using the In-Circuit Serial Programming™ (ICSP™) feature of the device. Each device Configuration register is a 24-bit register, but only the lower 16 bits of each register are used to hold configuration data. There are five device Configuration registers available to the user:

1. FOSC (0xF80000): Oscillator Configuration Register
2. FWDT (0xF80002): Watchdog Timer Configuration Register
3. FBORPOR (0xF80004): BOR and POR Configuration Register
4. FGS (0xF8000A): General Code Segment Configuration Register
5. FICD (0xF8000C): Debug Configuration Register

The placement of the Configuration bits is automatically handled when you select the device in your device programmer. The desired state of the Configuration bits may be specified in the source code (dependent on the language tool used), or through the programming interface. After the device has been programmed, the application software may read the Configuration bit values through the table read instructions. For additional information, please refer to the Programming Specifications of the device.

Note: If the code protection Configuration fuse bits (FGS<GCP> and FGS<GWRP>) have been programmed, an erase of the entire code-protected device is only possible at voltages $V_{DD} \geq 4.5V$.

17.8 Peripheral Module Disable (PMD) Registers

The Peripheral Module Disable (PMD) registers provide a method to disable a peripheral module by stopping all clock sources supplied to that module. When a peripheral is disabled via the appropriate PMD control bit, the peripheral is in a minimum power consumption state. The Control and Status registers associated with the peripheral will also be disabled so writes to those registers will have no effect and read values will be invalid.

A peripheral module will only be enabled if both the associated bit in the PMD register is cleared and the peripheral is supported by the specific dsPIC DSC variant. If the peripheral is present in the device, it is enabled in the PMD register by default.

Note 1: If a PMD bit is set, the corresponding module is disabled after a delay of 1 instruction cycle. Similarly, if a PMD bit is cleared, the corresponding module is enabled after a delay of 1 instruction cycle (assuming the module Control registers are already configured to enable module operation).

2: In dsPIC30F2011, dsPIC30F3012 and dsPIC30F2012 devices, the U2MD bit is readable and writable and will be read as '1' when set.

17.9 In-Circuit Debugger

When MPLAB® ICD 2 is selected as a Debugger, the In-Circuit Debugging functionality is enabled. This function allows simple debugging functions when used with MPLAB IDE. When the device has this feature enabled, some of the resources are not available for general use. These resources include the first 80 bytes of Data RAM and two I/O pins.

One of four pairs of Debug I/O pins may be selected by the user using configuration options in MPLAB IDE. These pin pairs are named EMUD/EMUC, EMUD1/EMUC1, EMUD2/EMUC2 and EMUD3/EMUC3.

In each case, the selected EMUD pin is the Emulation/Debug Data line, and the EMUC pin is the Emulation/Debug Clock line. These pins will interface to the MPLAB ICD 2 module available from Microchip. The selected pair of Debug I/O pins is used by MPLAB ICD 2 to send commands and receive responses, as well as to send and receive data. To use the In-Circuit Debugger function of the device, the design must implement ICSP connections to MCLR, VDD, VSS, PGC, PGD and the selected EMUDx/EMUCx pin pair.

This gives rise to two possibilities:

1. If EMUD/EMUC is selected as the Debug I/O pin pair, then only a 5-pin interface is required, as the EMUD and EMUC pin functions are multiplexed with the PGD and PGC pin functions in all dsPIC30F devices.
2. If EMUD1/EMUC1, EMUD2/EMUC2 or EMUD3/EMUC3 is selected as the Debug I/O pin pair, then a 7-pin interface is required, as the EMUDx/EMUCx pin functions (x = 1, 2 or 3) are not multiplexed with the PGD and PGC pin functions.

TABLE 17-7: SYSTEM INTEGRATION REGISTER MAP

| SFR Name | Address | Bit 15 | Bit 14 | Bit 13 | Bit 12 | Bit 11 | Bit 10 | Bit 9 | Bit 8 | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Reset State |
|----------|---------|--------|-----------|--------|--------|-----------|-----------|-------|-------|-----------|---------------------|--------|-------|--------|-------|---------|-------|---------------------|
| RCON | 0740 | TRAPR | IOPUWR | BGST | LVDEN | LVDL<3:0> | | | | EXTR | SWR | SWDTEN | WDTO | SLEEP | IDLE | BOR | POR | (Note 1) |
| OSCCON | 0742 | — | COSC<2:0> | | | — | NOSC<2:0> | | | POST<1:0> | | LOCK | — | CF | — | LPOSCEN | OSWEN | (Note 2) |
| OSCTUN | 0744 | — | — | — | — | — | — | — | — | — | — | — | — | TUN3 | TUN2 | TUN1 | TUN0 | (Note 2) |
| PMD1 | 0770 | — | — | T3MD | T2MD | T1MD | — | — | — | I2CMD | U2MD ⁽³⁾ | U1MD | — | SPI1MD | — | — | ADCMD | 0000 0000 0000 0000 |
| PMD2 | 0772 | — | — | — | — | — | — | IC2MD | IC1MD | — | — | — | — | — | — | OC2MD | OC1MD | 0000 0000 0000 0000 |

Legend: — = unimplemented bit, read as '0'

Note 1: Reset state depends on type of reset.

Note 2: Reset state depends on Configuration bits.

Note 3: Only available on dsPIC30F3013 devices.

TABLE 17-8: DEVICE CONFIGURATION REGISTER MAP

| Name | Address | Bit 15 | Bit 14 | Bit 13 | Bit 12 | Bit 11 | Bit 10 | Bit 9 | Bit 8 | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---------|---------|------------|--------|-------------------------|--------|--------|-----------------------|-------------------------|-------------------------|-------|-------|------------|----------|-------------------------|-------------------------|------------|-------|
| FOSC | F80000 | FCKSM<1:0> | | — | — | — | FOS<2:0> | | | — | — | — | FPR<4:0> | | | | |
| FWDTC | F80002 | FWDTCN | — | — | — | — | — | — | — | — | — | FWPSA<1:0> | | FWPSB<3:0> | | | |
| FBORPOR | F80004 | MCLREN | — | — | — | — | PWMPIN ⁽¹⁾ | HPOL ⁽¹⁾ | LPOL ⁽¹⁾ | BOREN | — | BORV<1:0> | | — | — | FPWRT<1:0> | |
| FBS | F80006 | — | — | Reserved ⁽²⁾ | | — | — | — | Reserved ⁽²⁾ | — | — | — | — | Reserved ⁽²⁾ | | | |
| FSS | F80008 | — | — | Reserved ⁽²⁾ | | — | — | Reserved ⁽²⁾ | | — | — | — | — | Reserved ⁽²⁾ | | | |
| FGS | F8000A | — | — | — | — | — | — | — | — | — | — | — | — | — | Reserved ⁽³⁾ | GCP | GWRP |
| FICD | F8000C | BKBUG | COE | — | — | — | — | — | — | — | — | — | — | — | — | ICS<1:0> | |

Legend: — = unimplemented bit, read as '0'

Note 1: These bits are reserved (read as '1' and must be programmed as '1').

Note 2: Reserved bits read as '1' and must be programmed as '1'.

Note 3: The FGS<2> bit is a read-only copy of the GCP bit (FGS<1>).

18.0 INSTRUCTION SET SUMMARY

Note: This data sheet summarizes features of this group of dsPIC30F devices and is not intended to be a complete reference source. For more information on the CPU, peripherals, register descriptions and general device functionality, refer to the “dsPIC30F Family Reference Manual” (DS70046). For more information on the device instruction set and programming, refer to the “dsPIC30F Programmer’s Reference Manual” (DS70030).

The dsPIC30F instruction set adds many enhancements to the previous PIC® MCU instruction sets, while maintaining an easy migration from PIC MCU instruction sets.

Most instructions are a single program memory word (24 bits). Only three instructions require two program memory locations.

Each single-word instruction is a 24-bit word divided into an 8-bit opcode which specifies the instruction type, and one or more operands which further specify the operation of the instruction.

The instruction set is highly orthogonal and is grouped into five basic categories:

- Word or byte-oriented operations
- Bit-oriented operations
- Literal operations
- DSP operations
- Control operations

Table 18-1 shows the general symbols used in describing the instructions.

The dsPIC30F instruction set summary in Table 18-2 lists all the instructions, along with the status flags affected by each instruction.

Most word or byte-oriented W register instructions (including barrel shift instructions) have three operands:

- The first source operand which is typically a register ‘Wb’ without any address modifier
- The second source operand which is typically a register ‘Ws’ with or without an address modifier
- The destination of the result which is typically a register ‘Wd’ with or without an address modifier

However, word or byte-oriented file register instructions have two operands:

- The file register specified by the value ‘f’
- The destination, which could either be the file register ‘f’ or the W0 register, which is denoted as ‘WREG’

Most bit-oriented instructions (including simple rotate/shift instructions) have two operands:

- The W register (with or without an address modifier) or file register (specified by the value of ‘Ws’ or ‘f’)
- The bit in the W register or file register (specified by a literal value or indirectly by the contents of register ‘Wb’)

The literal instructions that involve data movement may use some of the following operands:

- A literal value to be loaded into a W register or file register (specified by the value of ‘k’)
- The W register or file register where the literal value is to be loaded (specified by ‘Wb’ or ‘f’)

However, literal instructions that involve arithmetic or logical operations use some of the following operands:

- The first source operand which is a register ‘Wb’ without any address modifier
- The second source operand which is a literal value
- The destination of the result (only if not the same as the first source operand) which is typically a register ‘Wd’ with or without an address modifier

The MAC class of DSP instructions may use some of the following operands:

- The accumulator (A or B) to be used (required operand)
- The W registers to be used as the two operands
- The X and Y address space prefetch operations
- The X and Y address space prefetch destinations
- The accumulator write-back destination

The other DSP instructions do not involve any multiplication, and may include:

- The accumulator to be used (required)
- The source or destination operand (designated as Wso or Wdo, respectively) with or without an address modifier
- The amount of shift specified by a W register ‘Wn’ or a literal value

The control instructions may use some of the following operands:

- A program memory address
- The mode of the table read and table write instructions

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All instructions are a single word, except for certain double-word instructions, which were made double-word instructions so that all the required information is available in these 48 bits. In the second word, the 8 MSBs are '0's. If this second word is executed as an instruction (by itself), it will execute as a NOP.

Most single-word instructions are executed in a single instruction cycle, unless a conditional test is true or the program counter is changed as a result of the instruction. In these cases, the execution takes two instruction cycles with the additional instruction cycle(s) executed as a NOP. Notable exceptions are the BRA (unconditional/computed branch), indirect CALL/GOTO, all table reads and writes, and

RETURN/RETFIE instructions, which are single-word instructions but take two or three cycles. Certain instructions that involve skipping over the subsequent instruction require either two or three cycles if the skip is performed, depending on whether the instruction being skipped is a single-word or two-word instruction. Moreover, double-word moves require two cycles. The double-word instructions execute in two instruction cycles.

Note: For more details on the instruction set, refer to the *"MCU and DSC Programmer's Reference Manual"* (DS70157).

TABLE 18-1: SYMBOLS USED IN OPCODE DESCRIPTIONS

| Field | Description |
|-----------------|---|
| #text | Means literal defined by "text" |
| (text) | Means "content of text" |
| [text] | Means "the location addressed by text" |
| { } | Optional field or operation |
| <n:m> | Register bit field |
| .b | Byte mode selection |
| .d | Double-Word mode selection |
| .S | Shadow register select |
| .w | Word mode selection (default) |
| Acc | One of two accumulators {A, B} |
| AWB | Accumulator write-back destination address register $\in \{W13, [W13]++2\}$ |
| bit4 | 4-bit bit selection field (used in word addressed instructions) $\in \{0...15\}$ |
| C, DC, N, OV, Z | MCU Status bits: Carry, Digit Carry, Negative, Overflow, Sticky Zero |
| Expr | Absolute address, label or expression (resolved by the linker) |
| f | File register address $\in \{0x0000...0x1FFF\}$ |
| lit1 | 1-bit unsigned literal $\in \{0,1\}$ |
| lit4 | 4-bit unsigned literal $\in \{0...15\}$ |
| lit5 | 5-bit unsigned literal $\in \{0...31\}$ |
| lit8 | 8-bit unsigned literal $\in \{0...255\}$ |
| lit10 | 10-bit unsigned literal $\in \{0...255\}$ for Byte mode, $\{0:1023\}$ for Word mode |
| lit14 | 14-bit unsigned literal $\in \{0...16384\}$ |
| lit16 | 16-bit unsigned literal $\in \{0...65535\}$ |
| lit23 | 23-bit unsigned literal $\in \{0...8388608\}$; LSB must be 0 |
| None | Field does not require an entry, may be blank |
| OA, OB, SA, SB | DSP Status bits: ACCA Overflow, ACCB Overflow, ACCA Saturate, ACCB Saturate |
| PC | Program Counter |
| Slit10 | 10-bit signed literal $\in \{-512...511\}$ |
| Slit16 | 16-bit signed literal $\in \{-32768...32767\}$ |
| Slit6 | 6-bit signed literal $\in \{-16...16\}$ |

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TABLE 18-1: SYMBOLS USED IN OPCODE DESCRIPTIONS (CONTINUED)

| Field | Description |
|-------|---|
| Wb | Base W register $\in \{W0..W15\}$ |
| Wd | Destination W register $\in \{Wd, [Wd], [Wd++] , [Wd--], [++Wd], [--Wd] \}$ |
| Wdo | Destination W register $\in \{Wnd, [Wnd], [Wnd++] , [Wnd--], [++Wnd], [--Wnd], [Wnd+Wb] \}$ |
| Wm,Wn | Dividend, Divisor working register pair (direct addressing) |
| Wm*Wm | Multiplicand and Multiplier working register pair for Square instructions $\in \{W4*W4, W5*W5, W6*W6, W7*W7\}$ |
| Wm*Wn | Multiplicand and Multiplier working register pair for DSP instructions $\in \{W4*W5, W4*W6, W4*W7, W5*W6, W5*W7, W6*W7\}$ |
| Wn | One of 16 working registers $\in \{W0..W15\}$ |
| Wnd | One of 16 destination working registers $\in \{W0..W15\}$ |
| Wns | One of 16 source working registers $\in \{W0..W15\}$ |
| WREG | W0 (working register used in file register instructions) |
| Ws | Source W register $\in \{Ws, [Ws], [Ws++] , [Ws--], [++Ws], [--Ws] \}$ |
| Wso | Source W register $\in \{Wns, [Wns], [Wns++] , [Wns--], [++Wns], [--Wns], [Wns+Wb] \}$ |
| Wx | X data space prefetch address register for DSP instructions $\in \{[W8] += 6, [W8] += 4, [W8] += 2, [W8], [W8] -= 6, [W8] -= 4, [W8] -= 2, [W9] += 6, [W9] += 4, [W9] += 2, [W9], [W9] -= 6, [W9] -= 4, [W9] -= 2, [W9+W12], \text{none}\}$ |
| Wxd | X data space prefetch destination register for DSP instructions $\in \{W4..W7\}$ |
| Wy | Y data space prefetch address register for DSP instructions $\in \{[W10] += 6, [W10] += 4, [W10] += 2, [W10], [W10] -= 6, [W10] -= 4, [W10] -= 2, [W11] += 6, [W11] += 4, [W11] += 2, [W11], [W11] -= 6, [W11] -= 4, [W11] -= 2, [W11+W12], \text{none}\}$ |
| Wyd | Y data space prefetch destination register for DSP instructions $\in \{W4..W7\}$ |

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TABLE 18-2: INSTRUCTION SET OVERVIEW

| Base Instr # | Assembly Mnemonic | Assembly Syntax | Description | # of Words | # of Cycle s | Status Flags Affected |
|--------------|-------------------|----------------------|--|------------|--------------|-----------------------|
| 1 | ADD | ADD Acc | Add Accumulators | 1 | 1 | OA,OB,SA,SB |
| | | ADD f | $f = f + WREG$ | 1 | 1 | C,DC,N,OV,Z |
| | | ADD f, WREG | $WREG = f + WREG$ | 1 | 1 | C,DC,N,OV,Z |
| | | ADD #lit10, Wn | $Wd = lit10 + Wd$ | 1 | 1 | C,DC,N,OV,Z |
| | | ADD Wb, Ws, Wd | $Wd = Wb + Ws$ | 1 | 1 | C,DC,N,OV,Z |
| | | ADD Wb, #lit5, Wd | $Wd = Wb + lit5$ | 1 | 1 | C,DC,N,OV,Z |
| | | ADD Wso, #Slit4, Acc | 16-bit Signed Add to Accumulator | 1 | 1 | OA,OB,SA,SB |
| 2 | ADDC | ADDC f | $f = f + WREG + (C)$ | 1 | 1 | C,DC,N,OV,Z |
| | | ADDC f, WREG | $WREG = f + WREG + (C)$ | 1 | 1 | C,DC,N,OV,Z |
| | | ADDC #lit10, Wn | $Wd = lit10 + Wd + (C)$ | 1 | 1 | C,DC,N,OV,Z |
| | | ADDC Wb, Ws, Wd | $Wd = Wb + Ws + (C)$ | 1 | 1 | C,DC,N,OV,Z |
| | | ADDC Wb, #lit5, Wd | $Wd = Wb + lit5 + (C)$ | 1 | 1 | C,DC,N,OV,Z |
| 3 | AND | AND f | $f = f .AND. WREG$ | 1 | 1 | N,Z |
| | | AND f, WREG | $WREG = f .AND. WREG$ | 1 | 1 | N,Z |
| | | AND #lit10, Wn | $Wd = lit10 .AND. Wd$ | 1 | 1 | N,Z |
| | | AND Wb, Ws, Wd | $Wd = Wb .AND. Ws$ | 1 | 1 | N,Z |
| | | AND Wb, #lit5, Wd | $Wd = Wb .AND. lit5$ | 1 | 1 | N,Z |
| 4 | ASR | ASR f | $f = \text{Arithmetic Right Shift } f$ | 1 | 1 | C,N,OV,Z |
| | | ASR f, WREG | $WREG = \text{Arithmetic Right Shift } f$ | 1 | 1 | C,N,OV,Z |
| | | ASR Ws, Wd | $Wd = \text{Arithmetic Right Shift } Ws$ | 1 | 1 | C,N,OV,Z |
| | | ASR Wb, Wns, Wnd | $Wnd = \text{Arithmetic Right Shift } Wb \text{ by } Wns$ | 1 | 1 | N,Z |
| | | ASR Wb, #lit5, Wnd | $Wnd = \text{Arithmetic Right Shift } Wb \text{ by } lit5$ | 1 | 1 | N,Z |
| 5 | BCLR | BCLR f, #bit4 | Bit Clear f | 1 | 1 | None |
| | | BCLR Ws, #bit4 | Bit Clear Ws | 1 | 1 | None |
| 6 | BRA | BRA C, Expr | Branch if Carry | 1 | 1 (2) | None |
| | | BRA GE, Expr | Branch if greater than or equal | 1 | 1 (2) | None |
| | | BRA GEU, Expr | Branch if unsigned greater than or equal | 1 | 1 (2) | None |
| | | BRA GT, Expr | Branch if greater than | 1 | 1 (2) | None |
| | | BRA GTU, Expr | Branch if unsigned greater than | 1 | 1 (2) | None |
| | | BRA LE, Expr | Branch if less than or equal | 1 | 1 (2) | None |
| | | BRA LEU, Expr | Branch if unsigned less than or equal | 1 | 1 (2) | None |
| | | BRA LT, Expr | Branch if less than | 1 | 1 (2) | None |
| | | BRA LTU, Expr | Branch if unsigned less than | 1 | 1 (2) | None |
| | | BRA N, Expr | Branch if Negative | 1 | 1 (2) | None |
| | | BRA NC, Expr | Branch if Not Carry | 1 | 1 (2) | None |
| | | BRA NN, Expr | Branch if Not Negative | 1 | 1 (2) | None |
| | | BRA NOV, Expr | Branch if Not Overflow | 1 | 1 (2) | None |
| | | BRA NZ, Expr | Branch if Not Zero | 1 | 1 (2) | None |
| | | BRA OA, Expr | Branch if Accumulator A overflow | 1 | 1 (2) | None |
| | | BRA OB, Expr | Branch if Accumulator B overflow | 1 | 1 (2) | None |
| | | BRA OV, Expr | Branch if Overflow | 1 | 1 (2) | None |
| | | BRA SA, Expr | Branch if Accumulator A saturated | 1 | 1 (2) | None |
| | | BRA SB, Expr | Branch if Accumulator B saturated | 1 | 1 (2) | None |
| | | BRA Expr | Branch Unconditionally | 1 | 2 | None |
| | | BRA Z, Expr | Branch if Zero | 1 | 1 (2) | None |
| | | BRA Wn | Computed Branch | 1 | 2 | None |
| 7 | BSET | BSET f, #bit4 | Bit Set f | 1 | 1 | None |
| | | BSET Ws, #bit4 | Bit Set Ws | 1 | 1 | None |
| 8 | BSW | BSW.C Ws, Wb | Write C bit to Ws<Wb> | 1 | 1 | None |
| | | BSW.Z Ws, Wb | Write Z bit to Ws<Wb> | 1 | 1 | None |

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TABLE 18-2: INSTRUCTION SET OVERVIEW (CONTINUED)

| Base Instr # | Assembly Mnemonic | Assembly Syntax | Description | # of Words | # of Cycle s | Status Flags Affected |
|--------------|-------------------|----------------------------------|--|------------|---------------|-----------------------|
| 9 | BTG | BTG $f, \#bit4$ | Bit Toggle f | 1 | 1 | None |
| | | BTG $Ws, \#bit4$ | Bit Toggle Ws | 1 | 1 | None |
| 10 | BTSC | BTSC $f, \#bit4$ | Bit Test f , Skip if Clear | 1 | 1 (2 or 3) | None |
| | | BTSC $Ws, \#bit4$ | Bit Test Ws , Skip if Clear | 1 | 1 (2 or 3) | None |
| 11 | BTSS | BTSS $f, \#bit4$ | Bit Test f , Skip if Set | 1 | 1 (2 or 3) | None |
| | | BTSS $Ws, \#bit4$ | Bit Test Ws , Skip if Set | 1 | 1 (2 or 3) | None |
| 12 | BTST | BTST $f, \#bit4$ | Bit Test f | 1 | 1 | Z |
| | | BTST.C $Ws, \#bit4$ | Bit Test Ws to C | 1 | 1 | C |
| | | BTST.Z $Ws, \#bit4$ | Bit Test Ws to Z | 1 | 1 | Z |
| | | BTST.C Ws, Wb | Bit Test $Ws < Wb >$ to C | 1 | 1 | C |
| | | BTST.Z Ws, Wb | Bit Test $Ws < Wb >$ to Z | 1 | 1 | Z |
| 13 | BTSTS | BTSTS $f, \#bit4$ | Bit Test then Set f | 1 | 1 | Z |
| | | BTSTS.C $Ws, \#bit4$ | Bit Test Ws to C, then Set | 1 | 1 | C |
| | | BTSTS.Z $Ws, \#bit4$ | Bit Test Ws to Z, then Set | 1 | 1 | Z |
| 14 | CALL | CALL $lit23$ | Call subroutine | 2 | 2 | None |
| | | CALL Wn | Call indirect subroutine | 1 | 2 | None |
| 15 | CLR | CLR f | $f = 0x0000$ | 1 | 1 | None |
| | | CLR $WREG$ | $WREG = 0x0000$ | 1 | 1 | None |
| | | CLR Ws | $Ws = 0x0000$ | 1 | 1 | None |
| | | CLR $Acc, Wx, Wxd, Wy, Wyd, AWB$ | Clear Accumulator | 1 | 1 | OA,OB,SA,SB |
| 16 | CLRWDT | CLRWDT | Clear Watchdog Timer | 1 | 1 | WDTO,Sleep |
| 17 | COM | COM f | $f = \bar{f}$ | 1 | 1 | N,Z |
| | | COM $f, WREG$ | $WREG = \bar{f}$ | 1 | 1 | N,Z |
| | | COM Ws, Wd | $Wd = \overline{Ws}$ | 1 | 1 | N,Z |
| 18 | CP | CP f | Compare f with $WREG$ | 1 | 1 | C,DC,N,OV,Z |
| | | CP $Wb, \#lit5$ | Compare Wb with $lit5$ | 1 | 1 | C,DC,N,OV,Z |
| | | CP Wb, Ws | Compare Wb with Ws ($Wb - Ws$) | 1 | 1 | C,DC,N,OV,Z |
| 19 | CP0 | CP0 f | Compare f with $0x0000$ | 1 | 1 | C,DC,N,OV,Z |
| | | CP0 Ws | Compare Ws with $0x0000$ | 1 | 1 | C,DC,N,OV,Z |
| 20 | CPB | CPB f | Compare f with $WREG$, with Borrow | 1 | 1 | C,DC,N,OV,Z |
| | | CPB $Wb, \#lit5$ | Compare Wb with $lit5$, with Borrow | 1 | 1 | C,DC,N,OV,Z |
| | | CPB Wb, Ws | Compare Wb with Ws , with Borrow ($Wb - Ws - C$) | 1 | 1 | C,DC,N,OV,Z |
| 21 | CPSEQ | CPSEQ Wb, Wn | Compare Wb with Wn , skip if = | 1 | 1 (2 or 3) | None |
| 22 | CPSGT | CPSGT Wb, Wn | Compare Wb with Wn , skip if > | 1 | 1 (2 or 3) | None |
| 23 | CPSLT | CPSLT Wb, Wn | Compare Wb with Wn , skip if < | 1 | 1 (2 or 3) | None |
| 24 | CPSNE | CPSNE Wb, Wn | Compare Wb with Wn , skip if \neq | 1 | 1 (2 or 3) | None |
| 25 | DAW | DAW Wn | $Wn =$ decimal adjust Wn | 1 | 1 | C |
| 26 | DEC | DEC f | $f = f - 1$ | 1 | 1 | C,DC,N,OV,Z |
| | | DEC $f, WREG$ | $WREG = f - 1$ | 1 | 1 | C,DC,N,OV,Z |
| | | DEC Ws, Wd | $Wd = Ws - 1$ | 1 | 1 | C,DC,N,OV,Z |
| 27 | DEC2 | DEC2 f | $f = f - 2$ | 1 | 1 | C,DC,N,OV,Z |
| | | DEC2 $f, WREG$ | $WREG = f - 2$ | 1 | 1 | C,DC,N,OV,Z |
| | | DEC2 Ws, Wd | $Wd = Ws - 2$ | 1 | 1 | C,DC,N,OV,Z |
| 28 | DISI | DISI $\#lit14$ | Disable Interrupts for k instruction cycles | 1 | 1 | None |

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TABLE 18-2: INSTRUCTION SET OVERVIEW (CONTINUED)

| Base Instr # | Assembly Mnemonic | Assembly Syntax | Description | # of Words | # of Cycles | Status Flags Affected |
|--------------|-------------------|---------------------------------------|--------------------------------------|------------|-------------|-----------------------|
| 29 | DIV | DIV.S Wm, Wn | Signed 16/16-bit Integer Divide | 1 | 18 | N,Z,C,OV |
| | | DIV.SD Wm, Wn | Signed 32/16-bit Integer Divide | 1 | 18 | N,Z,C,OV |
| | | DIV.U Wm, Wn | Unsigned 16/16-bit Integer Divide | 1 | 18 | N,Z,C,OV |
| | | DIV.UD Wm, Wn | Unsigned 32/16-bit Integer Divide | 1 | 18 | N,Z,C,OV |
| 30 | DIVF | DIVF Wm, Wn | Signed 16/16-bit Fractional Divide | 1 | 18 | N,Z,C,OV |
| 31 | DO | DO #lit14, Expr | Do code to PC+Expr, lit14+1 times | 2 | 2 | None |
| | | DO Wn, Expr | Do code to PC+Expr, (Wn)+1 times | 2 | 2 | None |
| 32 | ED | ED Wm*Wm, Acc, Wx, Wy, Wxd | Euclidean Distance (no accumulate) | 1 | 1 | OA,OB,OAB,SA,SB,SAB |
| 33 | EDAC | EDAC Wm*Wm, Acc, Wx, Wy, Wxd | Euclidean Distance | 1 | 1 | OA,OB,OAB,SA,SB,SAB |
| 34 | EXCH | EXCH Wns, Wnd | Swap Wns with Wnd | 1 | 1 | None |
| 35 | FBCL | FBCL Ws, Wnd | Find Bit Change from Left (MSb) Side | 1 | 1 | C |
| 36 | FF1L | FF1L Ws, Wnd | Find First One from Left (MSb) Side | 1 | 1 | C |
| 37 | FF1R | FF1R Ws, Wnd | Find First One from Right (LSb) Side | 1 | 1 | C |
| 38 | GOTO | GOTO Expr | Go to address | 2 | 2 | None |
| | | GOTO Wn | Go to indirect | 1 | 2 | None |
| 39 | INC | INC f | f = f + 1 | 1 | 1 | C,DC,N,OV,Z |
| | | INC f, WREG | WREG = f + 1 | 1 | 1 | C,DC,N,OV,Z |
| | | INC Ws, Wd | Wd = Ws + 1 | 1 | 1 | C,DC,N,OV,Z |
| 40 | INC2 | INC2 f | f = f + 2 | 1 | 1 | C,DC,N,OV,Z |
| | | INC2 f, WREG | WREG = f + 2 | 1 | 1 | C,DC,N,OV,Z |
| | | INC2 Ws, Wd | Wd = Ws + 2 | 1 | 1 | C,DC,N,OV,Z |
| 41 | IOR | IOR f | f = f .IOR. WREG | 1 | 1 | N,Z |
| | | IOR f, WREG | WREG = f .IOR. WREG | 1 | 1 | N,Z |
| | | IOR #lit10, Wn | Wd = lit10 .IOR. Wd | 1 | 1 | N,Z |
| | | IOR Wb, Ws, Wd | Wd = Wb .IOR. Ws | 1 | 1 | N,Z |
| | | IOR Wb, #lit5, Wd | Wd = Wb .IOR. lit5 | 1 | 1 | N,Z |
| 42 | LAC | LAC Wso, #Slit4, Acc | Load Accumulator | 1 | 1 | OA,OB,OAB,SA,SB,SAB |
| 43 | LNK | LNK #lit14 | Link frame pointer | 1 | 1 | None |
| 44 | LSR | LSR f | f = Logical Right Shift f | 1 | 1 | C,N,OV,Z |
| | | LSR f, WREG | WREG = Logical Right Shift f | 1 | 1 | C,N,OV,Z |
| | | LSR Ws, Wd | Wd = Logical Right Shift Ws | 1 | 1 | C,N,OV,Z |
| | | LSR Wb, Wns, Wnd | Wnd = Logical Right Shift Wb by Wns | 1 | 1 | N,Z |
| | | LSR Wb, #lit5, Wnd | Wnd = Logical Right Shift Wb by lit5 | 1 | 1 | N,Z |
| 45 | MAC | MAC Wm*Wn, Acc, Wx, Wxd, Wy, Wyd, AWB | Multiply and Accumulate | 1 | 1 | OA,OB,OAB,SA,SB,SAB |
| | | MAC Wm*Wm, Acc, Wx, Wxd, Wy, Wyd | Square and Accumulate | 1 | 1 | OA,OB,OAB,SA,SB,SAB |
| 46 | MOV | MOV f, Wn | Move f to Wn | 1 | 1 | None |
| | | MOV f | Move f to f | 1 | 1 | N,Z |
| | | MOV f, WREG | Move f to WREG | 1 | 1 | N,Z |
| | | MOV #lit16, Wn | Move 16-bit literal to Wn | 1 | 1 | None |
| | | MOV.b #lit8, Wn | Move 8-bit literal to Wn | 1 | 1 | None |
| | | MOV Wn, f | Move Wn to f | 1 | 1 | None |
| | | MOV Wso, Wdo | Move Ws to Wd | 1 | 1 | None |
| | | MOV WREG, f | Move WREG to f | 1 | 1 | N,Z |
| | | MOV.D Wns, Wd | Move Double from W(ns):W(ns+1) to Wd | 1 | 2 | None |
| | | MOV.D Ws, Wnd | Move Double from Ws to W(nd+1):W(nd) | 1 | 2 | None |
| 47 | MOVSAC | MOVSAC Acc, Wx, Wxd, Wy, Wyd, AWB | Prefetch and store accumulator | 1 | 1 | None |

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TABLE 18-2: INSTRUCTION SET OVERVIEW (CONTINUED)

| Base Instr # | Assembly Mnemonic | Assembly Syntax | Description | # of Words | # of Cycles | Status Flags Affected |
|--------------|-------------------|---|--|------------|-------------|-----------------------|
| 48 | MPY | MPY $Wm * Wn, Acc, Wx, Wxd, Wy, Wyd$ | Multiply Wm by Wn to Accumulator | 1 | 1 | OA,OB,OAB,SA,SB,SAB |
| | | MPY $Wm * Wm, Acc, Wx, Wxd, Wy, Wyd$ | Square Wm to Accumulator | 1 | 1 | OA,OB,OAB,SA,SB,SAB |
| 49 | MPY.N | MPY.N $Wm * Wn, Acc, Wx, Wxd, Wy, Wyd$ | -(Multiply Wm by Wn) to Accumulator | 1 | 1 | None |
| 50 | MSC | MSC $Wm * Wm, Acc, Wx, Wxd, Wy, Wyd, AWB$ | Multiply and Subtract from Accumulator | 1 | 1 | OA,OB,OAB,SA,SB,SAB |
| 51 | MUL | MUL.SS Wb, Ws, Wnd | $\{Wnd+1, Wnd\} = \text{signed}(Wb) * \text{signed}(Ws)$ | 1 | 1 | None |
| | | MUL.SU Wb, Ws, Wnd | $\{Wnd+1, Wnd\} = \text{signed}(Wb) * \text{unsigned}(Ws)$ | 1 | 1 | None |
| | | MUL.US Wb, Ws, Wnd | $\{Wnd+1, Wnd\} = \text{unsigned}(Wb) * \text{signed}(Ws)$ | 1 | 1 | None |
| | | MUL.UU Wb, Ws, Wnd | $\{Wnd+1, Wnd\} = \text{unsigned}(Wb) * \text{unsigned}(Ws)$ | 1 | 1 | None |
| | | MUL.SU $Wb, \#lit5, Wnd$ | $\{Wnd+1, Wnd\} = \text{signed}(Wb) * \text{unsigned}(lit5)$ | 1 | 1 | None |
| | | MUL.UU $Wb, \#lit5, Wnd$ | $\{Wnd+1, Wnd\} = \text{unsigned}(Wb) * \text{unsigned}(lit5)$ | 1 | 1 | None |
| | | MUL f | $W3:W2 = f * WREG$ | 1 | 1 | None |
| 52 | NEG | NEG Acc | Negate Accumulator | 1 | 1 | OA,OB,OAB,SA,SB,SAB |
| | | NEG f | $f = \bar{f} + 1$ | 1 | 1 | C,DC,N,OV,Z |
| | | NEG $f, WREG$ | $WREG = \bar{f} + 1$ | 1 | 1 | C,DC,N,OV,Z |
| | | NEG Ws, Wd | $Wd = \overline{Ws} + 1$ | 1 | 1 | C,DC,N,OV,Z |
| 53 | NOP | NOP | No Operation | 1 | 1 | None |
| | | NOPR | No Operation | 1 | 1 | None |
| 54 | POP | POP f | Pop f from top-of-stack (TOS) | 1 | 1 | None |
| | | POP Wdo | Pop from top-of-stack (TOS) to Wdo | 1 | 1 | None |
| | | POP.D Wnd | Pop from top-of-stack (TOS) to $W(nd):W(nd+1)$ | 1 | 2 | None |
| | | POP.S | Pop Shadow Registers | 1 | 1 | All |
| 55 | PUSH | PUSH f | Push f to top-of-stack (TOS) | 1 | 1 | None |
| | | PUSH Wso | Push Wso to top-of-stack (TOS) | 1 | 1 | None |
| | | PUSH.D Wns | Push $W(ns):W(ns+1)$ to top-of-stack (TOS) | 1 | 2 | None |
| | | PUSH.S | Push Shadow Registers | 1 | 1 | None |
| 56 | PWRSV | PWRSV $\#lit1$ | Go into Sleep or Idle mode | 1 | 1 | WDTO,Sleep |
| 57 | RCALL | RCALL $Expr$ | Relative Call | 1 | 2 | None |
| | | RCALL Wn | Computed Call | 1 | 2 | None |
| 58 | REPEAT | REPEAT $\#lit14$ | Repeat Next Instruction $lit14+1$ times | 1 | 1 | None |
| | | REPEAT Wn | Repeat Next Instruction $(Wn)+1$ times | 1 | 1 | None |
| 59 | RESET | RESET | Software device Reset | 1 | 1 | None |
| 60 | RETFIE | RETFIE | Return from interrupt | 1 | 3 (2) | None |
| 61 | RETLW | RETLW $\#lit10, Wn$ | Return with literal in Wn | 1 | 3 (2) | None |
| 62 | RETURN | RETURN | Return from Subroutine | 1 | 3 (2) | None |
| 63 | RLC | RLC f | $f = \text{Rotate Left through Carry } f$ | 1 | 1 | C,N,Z |
| | | RLC $f, WREG$ | $WREG = \text{Rotate Left through Carry } f$ | 1 | 1 | C,N,Z |
| | | RLC Ws, Wd | $Wd = \text{Rotate Left through Carry } Ws$ | 1 | 1 | C,N,Z |
| 64 | RLNC | RLNC f | $f = \text{Rotate Left (No Carry) } f$ | 1 | 1 | N,Z |
| | | RLNC $f, WREG$ | $WREG = \text{Rotate Left (No Carry) } f$ | 1 | 1 | N,Z |
| | | RLNC Ws, Wd | $Wd = \text{Rotate Left (No Carry) } Ws$ | 1 | 1 | N,Z |
| 65 | RRC | RRC f | $f = \text{Rotate Right through Carry } f$ | 1 | 1 | C,N,Z |
| | | RRC $f, WREG$ | $WREG = \text{Rotate Right through Carry } f$ | 1 | 1 | C,N,Z |
| | | RRC Ws, Wd | $Wd = \text{Rotate Right through Carry } Ws$ | 1 | 1 | C,N,Z |

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TABLE 18-2: INSTRUCTION SET OVERVIEW (CONTINUED)

| Base Instr # | Assembly Mnemonic | Assembly Syntax | Description | # of Words | # of Cycles | Status Flags Affected |
|--------------|-------------------|---|--|------------|-------------|-----------------------|
| 66 | RRNC | RRNC <i>f</i> | <i>f</i> = Rotate Right (No Carry) <i>f</i> | 1 | 1 | N,Z |
| | | RRNC <i>f</i> , WREG | WREG = Rotate Right (No Carry) <i>f</i> | 1 | 1 | N,Z |
| | | RRNC <i>Ws</i> , <i>Wd</i> | <i>Wd</i> = Rotate Right (No Carry) <i>Ws</i> | 1 | 1 | N,Z |
| 67 | SAC | SAC <i>Acc</i> , #Slit4, <i>Wdo</i> | Store Accumulator | 1 | 1 | None |
| | | SAC.R <i>Acc</i> , #Slit4, <i>Wdo</i> | Store Rounded Accumulator | 1 | 1 | None |
| 68 | SE | SE <i>Ws</i> , <i>Wnd</i> | <i>Wnd</i> = sign-extended <i>Ws</i> | 1 | 1 | C,N,Z |
| 69 | SETM | SETM <i>f</i> | <i>f</i> = 0xFFFF | 1 | 1 | None |
| | | SETM WREG | WREG = 0xFFFF | 1 | 1 | None |
| | | SETM <i>Ws</i> | <i>Ws</i> = 0xFFFF | 1 | 1 | None |
| 70 | SFTAC | SFTAC <i>Acc</i> , <i>Wn</i> | Arithmetic Shift Accumulator by (<i>Wn</i>) | 1 | 1 | OA,OB,OAB,SA,SB,SAB |
| | | SFTAC <i>Acc</i> , #Slit6 | Arithmetic Shift Accumulator by Slit6 | 1 | 1 | OA,OB,OAB,SA,SB,SAB |
| 71 | SL | SL <i>f</i> | <i>f</i> = Left Shift <i>f</i> | 1 | 1 | C,N,OV,Z |
| | | SL <i>f</i> , WREG | WREG = Left Shift <i>f</i> | 1 | 1 | C,N,OV,Z |
| | | SL <i>Ws</i> , <i>Wd</i> | <i>Wd</i> = Left Shift <i>Ws</i> | 1 | 1 | C,N,OV,Z |
| | | SL <i>Wb</i> , <i>Wns</i> , <i>Wnd</i> | <i>Wnd</i> = Left Shift <i>Wb</i> by <i>Wns</i> | 1 | 1 | N,Z |
| | | SL <i>Wb</i> , #lit5, <i>Wnd</i> | <i>Wnd</i> = Left Shift <i>Wb</i> by lit5 | 1 | 1 | N,Z |
| 72 | SUB | SUB <i>Acc</i> | Subtract Accumulators | 1 | 1 | OA,OB,OAB,SA,SB,SAB |
| | | SUB <i>f</i> | <i>f</i> = <i>f</i> - WREG | 1 | 1 | C,DC,N,OV,Z |
| | | SUB <i>f</i> , WREG | WREG = <i>f</i> - WREG | 1 | 1 | C,DC,N,OV,Z |
| | | SUB #lit10, <i>Wn</i> | <i>Wn</i> = <i>Wn</i> - lit10 | 1 | 1 | C,DC,N,OV,Z |
| | | SUB <i>Wb</i> , <i>Ws</i> , <i>Wd</i> | <i>Wd</i> = <i>Wb</i> - <i>Ws</i> | 1 | 1 | C,DC,N,OV,Z |
| | | SUB <i>Wb</i> , #lit5, <i>Wd</i> | <i>Wd</i> = <i>Wb</i> - lit5 | 1 | 1 | C,DC,N,OV,Z |
| 73 | SUBB | SUBB <i>f</i> | <i>f</i> = <i>f</i> - WREG - (\overline{C}) | 1 | 1 | C,DC,N,OV,Z |
| | | SUBB <i>f</i> , WREG | WREG = <i>f</i> - WREG - (\overline{C}) | 1 | 1 | C,DC,N,OV,Z |
| | | SUBB #lit10, <i>Wn</i> | <i>Wn</i> = <i>Wn</i> - lit10 - (\overline{C}) | 1 | 1 | C,DC,N,OV,Z |
| | | SUBB <i>Wb</i> , <i>Ws</i> , <i>Wd</i> | <i>Wd</i> = <i>Wb</i> - <i>Ws</i> - (\overline{C}) | 1 | 1 | C,DC,N,OV,Z |
| | | SUBB <i>Wb</i> , #lit5, <i>Wd</i> | <i>Wd</i> = <i>Wb</i> - lit5 - (\overline{C}) | 1 | 1 | C,DC,N,OV,Z |
| 74 | SUBR | SUBR <i>f</i> | <i>f</i> = WREG - <i>f</i> | 1 | 1 | C,DC,N,OV,Z |
| | | SUBR <i>f</i> , WREG | WREG = WREG - <i>f</i> | 1 | 1 | C,DC,N,OV,Z |
| | | SUBR <i>Wb</i> , <i>Ws</i> , <i>Wd</i> | <i>Wd</i> = <i>Ws</i> - <i>Wb</i> | 1 | 1 | C,DC,N,OV,Z |
| | | SUBR <i>Wb</i> , #lit5, <i>Wd</i> | <i>Wd</i> = lit5 - <i>Wb</i> | 1 | 1 | C,DC,N,OV,Z |
| 75 | SUBBR | SUBBR <i>f</i> | <i>f</i> = WREG - <i>f</i> - (\overline{C}) | 1 | 1 | C,DC,N,OV,Z |
| | | SUBBR <i>f</i> , WREG | WREG = WREG - <i>f</i> - (\overline{C}) | 1 | 1 | C,DC,N,OV,Z |
| | | SUBBR <i>Wb</i> , <i>Ws</i> , <i>Wd</i> | <i>Wd</i> = <i>Ws</i> - <i>Wb</i> - (\overline{C}) | 1 | 1 | C,DC,N,OV,Z |
| | | SUBBR <i>Wb</i> , #lit5, <i>Wd</i> | <i>Wd</i> = lit5 - <i>Wb</i> - (\overline{C}) | 1 | 1 | C,DC,N,OV,Z |
| 76 | SWAP | SWAP.b <i>Wn</i> | <i>Wn</i> = nibble swap <i>Wn</i> | 1 | 1 | None |
| | | SWAP <i>Wn</i> | <i>Wn</i> = byte swap <i>Wn</i> | 1 | 1 | None |
| 77 | TBLRDH | TBLRDH <i>Ws</i> , <i>Wd</i> | Read Prog<23:16> to <i>Wd</i> <7:0> | 1 | 2 | None |
| 78 | TBLRDL | TBLRDL <i>Ws</i> , <i>Wd</i> | Read Prog<15:0> to <i>Wd</i> | 1 | 2 | None |
| 79 | TBLWTH | TBLWTH <i>Ws</i> , <i>Wd</i> | Write <i>Ws</i> <7:0> to Prog<23:16> | 1 | 2 | None |
| 80 | TBLWTL | TBLWTL <i>Ws</i> , <i>Wd</i> | Write <i>Ws</i> to Prog<15:0> | 1 | 2 | None |
| 81 | ULNK | ULNK | Unlink frame pointer | 1 | 1 | None |
| 82 | XOR | XOR <i>f</i> | <i>f</i> = <i>f</i> .XOR. WREG | 1 | 1 | N,Z |
| | | XOR <i>f</i> , WREG | WREG = <i>f</i> .XOR. WREG | 1 | 1 | N,Z |
| | | XOR #lit10, <i>Wn</i> | <i>Wd</i> = lit10 .XOR. <i>Wd</i> | 1 | 1 | N,Z |
| | | XOR <i>Wb</i> , <i>Ws</i> , <i>Wd</i> | <i>Wd</i> = <i>Wb</i> .XOR. <i>Ws</i> | 1 | 1 | N,Z |
| | | XOR <i>Wb</i> , #lit5, <i>Wd</i> | <i>Wd</i> = <i>Wb</i> .XOR. lit5 | 1 | 1 | N,Z |
| 83 | ZE | ZE <i>Ws</i> , <i>Wnd</i> | <i>Wnd</i> = Zero-extend <i>Ws</i> | 1 | 1 | C,Z,N |

19.0 DEVELOPMENT SUPPORT

The PIC® microcontrollers and dsPIC® digital signal controllers are supported with a full range of software and hardware development tools:

- Integrated Development Environment
 - MPLAB® IDE Software
- Compilers/Assemblers/Linkers
 - MPLAB C Compiler for Various Device Families
 - HI-TECH C for Various Device Families
 - MPASM™ Assembler
 - MPLINK™ Object Linker/
MPLIB™ Object Librarian
 - MPLAB Assembler/Linker/Librarian for Various Device Families
- Simulators
 - MPLAB SIM Software Simulator
- Emulators
 - MPLAB REAL ICE™ In-Circuit Emulator
- In-Circuit Debuggers
 - MPLAB ICD 3
 - PICKit™ 3 Debug Express
- Device Programmers
 - PICKit™ 2 Programmer
 - MPLAB PM3 Device Programmer
- Low-Cost Demonstration/Development Boards, Evaluation Kits, and Starter Kits

19.1 MPLAB Integrated Development Environment Software

The MPLAB IDE software brings an ease of software development previously unseen in the 8/16/32-bit microcontroller market. The MPLAB IDE is a Windows® operating system-based application that contains:

- A single graphical interface to all debugging tools
 - Simulator
 - Programmer (sold separately)
 - In-Circuit Emulator (sold separately)
 - In-Circuit Debugger (sold separately)
- A full-featured editor with color-coded context
- A multiple project manager
- Customizable data windows with direct edit of contents
- High-level source code debugging
- Mouse over variable inspection
- Drag and drop variables from source to watch windows
- Extensive on-line help
- Integration of select third party tools, such as IAR C Compilers

The MPLAB IDE allows you to:

- Edit your source files (either C or assembly)
- One-touch compile or assemble, and download to emulator and simulator tools (automatically updates all project information)
- Debug using:
 - Source files (C or assembly)
 - Mixed C and assembly
 - Machine code

MPLAB IDE supports multiple debugging tools in a single development paradigm, from the cost-effective simulators, through low-cost in-circuit debuggers, to full-featured emulators. This eliminates the learning curve when upgrading to tools with increased flexibility and power.

19.2 MPLAB C Compilers for Various Device Families

The MPLAB C Compiler code development systems are complete ANSI C compilers for Microchip's PIC18, PIC24 and PIC32 families of microcontrollers and the dsPIC30 and dsPIC33 families of digital signal controllers. These compilers provide powerful integration capabilities, superior code optimization and ease of use.

For easy source level debugging, the compilers provide symbol information that is optimized to the MPLAB IDE debugger.

19.3 HI-TECH C for Various Device Families

The HI-TECH C Compiler code development systems are complete ANSI C compilers for Microchip's PIC family of microcontrollers and the dsPIC family of digital signal controllers. These compilers provide powerful integration capabilities, omniscient code generation and ease of use.

For easy source level debugging, the compilers provide symbol information that is optimized to the MPLAB IDE debugger.

The compilers include a macro assembler, linker, pre-processor, and one-step driver, and can run on multiple platforms.

19.4 MPASM Assembler

The MPASM Assembler is a full-featured, universal macro assembler for PIC10/12/16/18 MCUs.

The MPASM Assembler generates relocatable object files for the MPLINK Object Linker, Intel® standard HEX files, MAP files to detail memory usage and symbol reference, absolute LST files that contain source lines and generated machine code and COFF files for debugging.

The MPASM Assembler features include:

- Integration into MPLAB IDE projects
- User-defined macros to streamline assembly code
- Conditional assembly for multi-purpose source files
- Directives that allow complete control over the assembly process

19.5 MPLINK Object Linker/ MPLIB Object Librarian

The MPLINK Object Linker combines relocatable objects created by the MPASM Assembler and the MPLAB C18 C Compiler. It can link relocatable objects from precompiled libraries, using directives from a linker script.

The MPLIB Object Librarian manages the creation and modification of library files of precompiled code. When a routine from a library is called from a source file, only the modules that contain that routine will be linked in with the application. This allows large libraries to be used efficiently in many different applications.

The object linker/librarian features include:

- Efficient linking of single libraries instead of many smaller files
- Enhanced code maintainability by grouping related modules together
- Flexible creation of libraries with easy module listing, replacement, deletion and extraction

19.6 MPLAB Assembler, Linker and Librarian for Various Device Families

MPLAB Assembler produces relocatable machine code from symbolic assembly language for PIC24, PIC32 and dsPIC devices. MPLAB C Compiler uses the assembler to produce its object file. The assembler generates relocatable object files that can then be archived or linked with other relocatable object files and archives to create an executable file. Notable features of the assembler include:

- Support for the entire device instruction set
- Support for fixed-point and floating-point data
- Command line interface
- Rich directive set
- Flexible macro language
- MPLAB IDE compatibility

19.7 MPLAB SIM Software Simulator

The MPLAB SIM Software Simulator allows code development in a PC-hosted environment by simulating the PIC MCUs and dsPIC® DSCs on an instruction level. On any given instruction, the data areas can be examined or modified and stimuli can be applied from a comprehensive stimulus controller. Registers can be logged to files for further run-time analysis. The trace buffer and logic analyzer display extend the power of the simulator to record and track program execution, actions on I/O, most peripherals and internal registers.

The MPLAB SIM Software Simulator fully supports symbolic debugging using the MPLAB C Compilers, and the MPASM and MPLAB Assemblers. The software simulator offers the flexibility to develop and debug code outside of the hardware laboratory environment, making it an excellent, economical software development tool.

19.8 MPLAB REAL ICE In-Circuit Emulator System

MPLAB REAL ICE In-Circuit Emulator System is Microchip's next generation high-speed emulator for Microchip Flash DSC and MCU devices. It debugs and programs PIC® Flash MCUs and dsPIC® Flash DSCs with the easy-to-use, powerful graphical user interface of the MPLAB Integrated Development Environment (IDE), included with each kit.

The emulator is connected to the design engineer's PC using a high-speed USB 2.0 interface and is connected to the target with either a connector compatible with in-circuit debugger systems (RJ11) or with the new high-speed, noise tolerant, Low-Voltage Differential Signal (LVDS) interconnection (CAT5).

The emulator is field upgradable through future firmware downloads in MPLAB IDE. In upcoming releases of MPLAB IDE, new devices will be supported, and new features will be added. MPLAB REAL ICE offers significant advantages over competitive emulators including low-cost, full-speed emulation, run-time variable watches, trace analysis, complex breakpoints, a ruggedized probe interface and long (up to three meters) interconnection cables.

19.9 MPLAB ICD 3 In-Circuit Debugger System

MPLAB ICD 3 In-Circuit Debugger System is Microchip's most cost effective high-speed hardware debugger/programmer for Microchip Flash Digital Signal Controller (DSC) and microcontroller (MCU) devices. It debugs and programs PIC® Flash microcontrollers and dsPIC® DSCs with the powerful, yet easy-to-use graphical user interface of MPLAB Integrated Development Environment (IDE).

The MPLAB ICD 3 In-Circuit Debugger probe is connected to the design engineer's PC using a high-speed USB 2.0 interface and is connected to the target with a connector compatible with the MPLAB ICD 2 or MPLAB REAL ICE systems (RJ-11). MPLAB ICD 3 supports all MPLAB ICD 2 headers.

19.10 PICkit 3 In-Circuit Debugger/Programmer and PICkit 3 Debug Express

The MPLAB PICkit 3 allows debugging and programming of PIC® and dsPIC® Flash microcontrollers at a most affordable price point using the powerful graphical user interface of the MPLAB Integrated Development Environment (IDE). The MPLAB PICkit 3 is connected to the design engineer's PC using a full speed USB interface and can be connected to the target via an Microchip debug (RJ-11) connector (compatible with MPLAB ICD 3 and MPLAB REAL ICE). The connector uses two device I/O pins and the reset line to implement in-circuit debugging and In-Circuit Serial Programming™.

The PICkit 3 Debug Express include the PICkit 3, demo board and microcontroller, hookup cables and CDROM with user's guide, lessons, tutorial, compiler and MPLAB IDE software.

19.11 PICkit 2 Development Programmer/Debugger and PICkit 2 Debug Express

The PICkit™ 2 Development Programmer/Debugger is a low-cost development tool with an easy to use interface for programming and debugging Microchip's Flash families of microcontrollers. The full featured Windows® programming interface supports baseline (PIC10F, PIC12F5xx, PIC16F5xx), midrange (PIC12F6xx, PIC16F), PIC18F, PIC24, dsPIC30, dsPIC33, and PIC32 families of 8-bit, 16-bit, and 32-bit microcontrollers, and many Microchip Serial EEPROM products. With Microchip's powerful MPLAB Integrated Development Environment (IDE) the PICkit™ 2 enables in-circuit debugging on most PIC® microcontrollers. In-Circuit-Debugging runs, halts and single steps the program while the PIC microcontroller is embedded in the application. When halted at a breakpoint, the file registers can be examined and modified.

The PICkit 2 Debug Express include the PICkit 2, demo board and microcontroller, hookup cables and CDROM with user's guide, lessons, tutorial, compiler and MPLAB IDE software.

19.12 MPLAB PM3 Device Programmer

The MPLAB PM3 Device Programmer is a universal, CE compliant device programmer with programmable voltage verification at VDDMIN and VDDMAX for maximum reliability. It features a large LCD display (128 x 64) for menus and error messages and a modular, detachable socket assembly to support various package types. The ICSP™ cable assembly is included as a standard item. In Stand-Alone mode, the MPLAB PM3 Device Programmer can read, verify and program PIC devices without a PC connection. It can also set code protection in this mode. The MPLAB PM3 connects to the host PC via an RS-232 or USB cable. The MPLAB PM3 has high-speed communications and optimized algorithms for quick programming of large memory devices and incorporates an MMC card for file storage and data applications.

19.13 Demonstration/Development Boards, Evaluation Kits, and Starter Kits

A wide variety of demonstration, development and evaluation boards for various PIC MCUs and dsPIC DSCs allows quick application development on fully functional systems. Most boards include prototyping areas for adding custom circuitry and provide application firmware and source code for examination and modification.

The boards support a variety of features, including LEDs, temperature sensors, switches, speakers, RS-232 interfaces, LCD displays, potentiometers and additional EEPROM memory.

The demonstration and development boards can be used in teaching environments, for prototyping custom circuits and for learning about various microcontroller applications.

In addition to the PICDEM™ and dsPICDEM™ demonstration/development board series of circuits, Microchip has a line of evaluation kits and demonstration software for analog filter design, KEELOQ® security ICs, CAN, IrDA®, PowerSmart battery management, SEEVAL® evaluation system, Sigma-Delta ADC, flow rate sensing, plus many more.

Also available are starter kits that contain everything needed to experience the specified device. This usually includes a single application and debug capability, all on one board.

Check the Microchip web page (www.microchip.com) for the complete list of demonstration, development and evaluation kits.

20.0 ELECTRICAL CHARACTERISTICS

This section provides an overview of dsPIC30F electrical characteristics. Additional information will be provided in future revisions of this document as it becomes available.

For detailed information about the dsPIC30F architecture and core, refer to the “dsPIC30F Family Reference Manual” (DS70046).

Absolute maximum ratings for the dsPIC30F family are listed below. Exposure to these maximum rating conditions for extended periods may affect device reliability. Functional operation of the device at these or any other conditions above the parameters indicated in the operation listings of this specification is not implied.

Absolute Maximum Ratings^(†)

| | |
|--|-----------------------|
| Ambient temperature under bias | -40°C to +125°C |
| Storage temperature | -65°C to +150°C |
| Voltage on any pin with respect to VSS (except VDD and MCLR) (Note 1) | -0.3V to (VDD + 0.3V) |
| Voltage on VDD with respect to VSS | -0.3V to +5.5V |
| Voltage on MCLR with respect to VSS | 0V to +13.25V |
| Maximum current out of VSS pin | 300 mA |
| Maximum current into VDD pin (Note 2) | 250 mA |
| Input clamp current, I _{IK} (V _I < 0 or V _I > VDD) | ±20 mA |
| Output clamp current, I _{OK} (V _O < 0 or V _O > VDD) | ±20 mA |
| Maximum output current sunk by any I/O pin | 25 mA |
| Maximum output current sourced by any I/O pin | 25 mA |
| Maximum current sunk by all ports | 200 mA |
| Maximum current sourced by all ports (Note 2) | 200 mA |

Note 1: Voltage spikes below VSS at the MCLR/VPP pin, inducing currents greater than 80 mA, may cause latch-up. Thus, a series resistor of 50-100Ω should be used when applying a “low” level to the MCLR/VPP pin, rather than pulling this pin directly to VSS.

2: Maximum allowable current is a function of device maximum power dissipation. See [Table 20-2](#) for P_{DMAX}.

†NOTICE: Stresses above those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operation listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

Note: All peripheral electrical characteristics are specified. For exact peripherals available on specific devices, please refer to the [dsPIC30F2011/2012/3012/3013 Sensor Family](#) table on page 4 of this data sheet.

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20.1 DC Characteristics

TABLE 20-1: OPERATING MIPS VS. VOLTAGE

| VDD Range | Temp Range | Max MIPS | |
|-----------|----------------|-----------------|-----------------|
| | | dsPIC30FXXX-30I | dsPIC30FXXX-20E |
| 4.5-5.5V | -40°C to 85°C | 30 | — |
| 4.5-5.5V | -40°C to 125°C | — | 20 |
| 3.0-3.6V | -40°C to 85°C | 20 | — |
| 3.0-3.6V | -40°C to 125°C | — | 15 |
| 2.5-3.0V | -40°C to 85°C | 10 | — |

TABLE 20-2: THERMAL OPERATING CONDITIONS

| Rating | Symbol | Min | Typ | Max | Unit |
|--|--------|---------------------------|-----|------|------|
| dsPIC30F201x-30I dsPIC30F301x-30I | | | | | |
| Operating Junction Temperature Range | TJ | -40 | — | +125 | °C |
| Operating Ambient Temperature Range | TA | -40 | — | +85 | °C |
| dsPIC30F201x-20E dsPIC30F301x-20E | | | | | |
| Operating Junction Temperature Range | TJ | -40 | — | +150 | °C |
| Operating Ambient Temperature Range | TA | -40 | — | +125 | °C |
| Power Dissipation: Internal chip power dissipation: $P_{INT} = V_{DD} \times (I_{DD} - \sum I_{OH})$ I/O Pin power dissipation: $P_{I/O} = \sum (\{V_{DD} - V_{OH}\} \times I_{OH}) + \sum (V_{OL} \times I_{OL})$ | PD | PINT + PI/O | | | W |
| Maximum Allowed Power Dissipation | PDMAX | (TJ - TA) / θ_{JA} | | | W |

TABLE 20-3: THERMAL PACKAGING CHARACTERISTICS

| Characteristic | Symbol | Typ | Max | Unit | Notes |
|---|---------------|-----|-----|------|-------|
| Package Thermal Resistance, 18-pin PDIP (P) | θ_{JA} | 44 | — | °C/W | 1 |
| Package Thermal Resistance, 18-pin SOIC (SO) | θ_{JA} | 57 | — | °C/W | 1 |
| Package Thermal Resistance, 28-pin SPDIP (SP) | θ_{JA} | 42 | — | °C/W | 1 |
| Package Thermal Resistance, 28-pin (SOIC) | θ_{JA} | 49 | — | °C/W | 1 |
| Package Thermal Resistance, 44-pin QFN | θ_{JA} | 28 | — | °C/W | 1 |

Note 1: Junction to ambient thermal resistance, Theta-ja (θ_{JA}) numbers are achieved by package simulations.

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TABLE 20-4: DC TEMPERATURE AND VOLTAGE SPECIFICATIONS

| DC CHARACTERISTICS | | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤ TA ≤ +85°C for Industrial -40°C ≤ TA ≤ +125°C for Extended | | | | |
|--|--------|---|---|--------------------|-----|-------|----------------------------------|
| Param No. | Symbol | Characteristic | Min | Typ ⁽¹⁾ | Max | Units | Conditions |
| Operating Voltage⁽²⁾ | | | | | | | |
| DC10 | VDD | Supply Voltage | 2.5 | — | 5.5 | V | Industrial temperature |
| DC11 | VDD | Supply Voltage | 3.0 | — | 5.5 | V | Extended temperature |
| DC12 | VDR | RAM Data Retention Voltage⁽³⁾ | 1.75 | — | — | V | |
| DC16 | VPOR | VDD Start Voltage (to ensure internal Power-on Reset signal) | — | — | VSS | V | |
| DC17 | SVDD | VDD Rise Rate (to ensure internal Power-on Reset signal) | 0.05 | — | — | V/ms | 0-5V in 0.1 sec 0-3V in 60 ms |

Note 1: “Typ” column data is at 5V, 25°C unless otherwise stated. Parameters are for design guidance only and are not tested.

2: These parameters are characterized but not tested in manufacturing.

3: This is the limit to which VDD can be lowered without losing RAM data.

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TABLE 20-5: DC CHARACTERISTICS: OPERATING CURRENT (IDD)

| DC CHARACTERISTICS | | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤TA ≤+85°C for Industrial -40°C ≤TA ≤+125°C for Extended | | |
|--|------------------------|-------|--|------------|------------------------------|
| Parameter No. | Typical ⁽¹⁾ | Max | Units | Conditions | |
| Operating Current (IDD) ⁽²⁾ | | | | | |
| DC31a | 1.6 | 3.0 | mA | 25°C | 0.128 MIPS LPRC (512 kHz) |
| DC31b | 1.6 | 3.0 | mA | 85°C | |
| DC31c | 1.6 | 3.0 | mA | 125°C | |
| DC31e | 3.6 | 6.0 | mA | 25°C | |
| DC31f | 3.3 | 6.0 | mA | 85°C | |
| DC31g | 3.2 | 6.0 | mA | 125°C | |
| DC30a | 3.0 | 5.0 | mA | 25°C | (1.8 MIPS) FRC (7.37 MHz) |
| DC30b | 3.0 | 5.0 | mA | 85°C | |
| DC30c | 3.1 | 5.0 | mA | 125°C | |
| DC30e | 6.0 | 9.0 | mA | 25°C | |
| DC30f | 5.8 | 9.0 | mA | 85°C | |
| DC30g | 5.7 | 9.0 | mA | 125°C | |
| DC23a | 9.0 | 15.0 | mA | 25°C | 4 MIPS |
| DC23b | 10.0 | 15.0 | mA | 85°C | |
| DC23c | 10.0 | 15.0 | mA | 125°C | |
| DC23e | 16.0 | 24.0 | mA | 25°C | |
| DC23f | 16.0 | 24.0 | mA | 85°C | |
| DC23g | 16.0 | 24.0 | mA | 125°C | |
| DC24a | 22.0 | 33.0 | mA | 25°C | 10 MIPS |
| DC24b | 22.0 | 33.0 | mA | 85°C | |
| DC24c | 22.0 | 33.0 | mA | 125°C | |
| DC24e | 37.0 | 56.0 | mA | 25°C | |
| DC24f | 37.0 | 56.0 | mA | 85°C | |
| DC24g | 37.0 | 56.0 | mA | 125°C | |
| DC27a | 41.0 | 60.0 | mA | 25°C | 20 MIPS |
| DC27b | 40.0 | 60.0 | mA | 85°C | |
| DC27d | 68.0 | 90.0 | mA | 25°C | |
| DC27e | 67.0 | 90.0 | mA | 85°C | |
| DC27f | 66.0 | 90.0 | mA | 125°C | |
| DC29a | 96.0 | 140.0 | mA | 25°C | |
| DC29b | 94.0 | 140.0 | mA | 85°C | 30 MIPS |

Note 1: Data in "Typical" column is at 5V, 25°C unless otherwise stated. Parameters are for design guidance only and are not tested.

- 2:** The supply current is mainly a function of the operating voltage and frequency. Other factors such as I/O pin loading and switching rate, oscillator type, internal code execution pattern and temperature also have an impact on the current consumption. The test conditions for all IDD measurements are as follows: OSC1 driven with external square wave from rail to rail. All I/O pins are configured as Inputs and pulled to VDD. MCLR = VDD, WDT, FSCM, LVD and BOR are disabled. CPU, SRAM, Program Memory and Data Memory are operational. No peripheral modules are operating.

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TABLE 20-6: DC CHARACTERISTICS: IDLE CURRENT (I_{IDLE})

| DC CHARACTERISTICS | | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤TA ≤+85°C for Industrial -40°C ≤TA ≤+125°C for Extended | | |
|--|------------------------|------|--|------------|------------------------------|
| Parameter No. | Typical ⁽¹⁾ | Max | Units | Conditions | |
| Operating Current (IDD) ⁽²⁾ | | | | | |
| DC51a | 1.3 | 2.5 | mA | 25°C | 0.128 MIPS LPRC (512 kHz) |
| DC51b | 1.3 | 2.5 | mA | 85°C | |
| DC51c | 1.2 | 2.5 | mA | 125°C | |
| DC51e | 3.2 | 5.0 | mA | 25°C | |
| DC51f | 2.9 | 5.0 | mA | 85°C | |
| DC51g | 2.8 | 5.0 | mA | 125°C | |
| DC50a | 3.0 | 5.0 | mA | 25°C | (1.8 MIPS) FRC (7.37 MHz) |
| DC50b | 3.0 | 5.0 | mA | 85°C | |
| DC50c | 3.0 | 5.0 | mA | 125°C | |
| DC50e | 6.0 | 9.0 | mA | 25°C | |
| DC50f | 5.8 | 9.0 | mA | 85°C | |
| DC50g | 5.7 | 9.0 | mA | 125°C | |
| DC43a | 5.2 | 8.0 | mA | 25°C | 4 MIPS |
| DC43b | 5.3 | 8.0 | mA | 85°C | |
| DC43c | 5.4 | 8.0 | mA | 125°C | |
| DC43e | 9.7 | 15.0 | mA | 25°C | |
| DC43f | 9.6 | 15.0 | mA | 85°C | |
| DC43g | 9.5 | 15.0 | mA | 125°C | |
| DC44a | 11.0 | 17.0 | mA | 25°C | 10 MIPS |
| DC44b | 11.0 | 17.0 | mA | 85°C | |
| DC44c | 11.0 | 17.0 | mA | 125°C | |
| DC44e | 19.0 | 29.0 | mA | 25°C | |
| DC44f | 19.0 | 29.0 | mA | 85°C | |
| DC44g | 20.0 | 30.0 | mA | 125°C | |
| DC47a | 20.0 | 35.0 | mA | 25°C | 20 MIPS |
| DC47b | 21.0 | 35.0 | mA | 85°C | |
| DC47d | 35.0 | 50.0 | mA | 25°C | |
| DC47e | 36.0 | 50.0 | mA | 85°C | |
| DC47f | 36.0 | 50.0 | mA | 125°C | |
| DC49a | 51.0 | 70.0 | mA | 25°C | |
| DC49b | 51.0 | 70.0 | mA | 85°C | 30 MIPS |

Note 1: Data in “Typical” column is at 5V, 25°C unless otherwise stated. Parameters are for design guidance only and are not tested.

2: Base I_{IDLE} current is measured with Core off, Clock on and all modules turned off.

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TABLE 20-7: DC CHARACTERISTICS: POWER-DOWN CURRENT (IPD)

| DC CHARACTERISTICS | | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤TA ≤+85°C for Industrial -40°C ≤TA ≤+125°C for Extended | | | |
|---|------------------------|------|--|------------|------|--|
| Parameter No. | Typical ⁽¹⁾ | Max | Units | Conditions | | |
| Power-Down Current (IPD) ⁽²⁾ | | | | | | |
| DC60a | 0.3 | — | μA | 25°C | 3.3V | Base Power-Down Current ⁽³⁾ |
| DC60b | 1.3 | 30.0 | μA | 85°C | | |
| DC60c | 16.0 | 60.0 | μA | 125°C | | |
| DC60e | 0.5 | — | μA | 25°C | 5V | |
| DC60f | 3.7 | 45.0 | μA | 85°C | | |
| DC60g | 25.0 | 90.0 | μA | 125°C | | |
| DC61a | 6.0 | 9.0 | μA | 25°C | 3.3V | Watchdog Timer Current: ΔIWD _T ⁽³⁾ |
| DC61b | 6.0 | 9.0 | μA | 85°C | | |
| DC61c | 6.0 | 9.0 | μA | 125°C | | |
| DC61e | 13.0 | 20.0 | μA | 25°C | 5V | |
| DC61f | 12.0 | 20.0 | μA | 85°C | | |
| DC61g | 12.0 | 20.0 | μA | 125°C | | |
| DC62a | 4.0 | 10.0 | μA | 25°C | 3.3V | Timer1 w/32 kHz Crystal: ΔIT ₁₃₂ ⁽³⁾ |
| DC62b | 5.0 | 10.0 | μA | 85°C | | |
| DC62c | 4.0 | 10.0 | μA | 125°C | | |
| DC62e | 4.0 | 15.0 | μA | 25°C | 5V | |
| DC62f | 6.0 | 15.0 | μA | 85°C | | |
| DC62g | 5.0 | 15.0 | μA | 125°C | | |
| DC63a | 33.0 | 53.0 | μA | 25°C | 3.3V | BOR On: ΔIBOR ⁽³⁾ |
| DC63b | 35.0 | 53.0 | μA | 85°C | | |
| DC63c | 19.0 | 53.0 | μA | 125°C | | |
| DC63e | 38.0 | 62.0 | μA | 25°C | 5V | |
| DC63f | 41.0 | 62.0 | μA | 85°C | | |
| DC63g | 41.0 | 62.0 | μA | 125°C | | |
| DC66a | 21.0 | 40.0 | μA | 25°C | 3.3V | Low-Voltage Detect: ΔILVD ⁽³⁾ |
| DC66b | 26.0 | 40.0 | μA | 85°C | | |
| DC66c | 27.0 | 40.0 | μA | 125°C | | |
| DC66e | 25.0 | 44.0 | μA | 25°C | 5V | |
| DC66f | 27.0 | 44.0 | μA | 85°C | | |
| DC66g | 29.0 | 44.0 | μA | 125°C | | |

Note 1: Data in the Typical column is at 5V, 25°C unless otherwise stated. Parameters are for design guidance only and are not tested.

2: Base IPD is measured with all peripherals and clocks shut down. All I/Os are configured as inputs and pulled high. LVD, BOR, WDT, etc. are all switched off.

3: The Δ current is the additional current consumed when the module is enabled. This current should be added to the base IPD current.

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TABLE 20-8: DC CHARACTERISTICS: I/O PIN INPUT SPECIFICATIONS

| DC CHARACTERISTICS | | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤ TA ≤ +85°C for Industrial -40°C ≤ TA ≤ +125°C for Extended | | | | |
|--------------------|-----------------|---|---|--------------------|---------------------|-------|--|
| Param No. | Symbol | Characteristic | Min | Typ ⁽¹⁾ | Max | Units | Conditions |
| DI10 | V _{IL} | Input Low Voltage⁽²⁾ I/O pins: with Schmitt Trigger buffer | V _{SS} | — | 0.2 V _{DD} | V | |
| DI15 | | <u>MCLR</u> | V _{SS} | — | 0.2 V _{DD} | V | |
| DI16 | | OSC1 (in XT, HS and LP modes) | V _{SS} | — | 0.2 V _{DD} | V | |
| DI17 | | OSC1 (in RC mode) ⁽³⁾ | V _{SS} | — | 0.3 V _{DD} | V | |
| DI18 | | SDA, SCL | V _{SS} | — | 0.3 V _{DD} | V | SM bus disabled |
| DI19 | | SDA, SCL | V _{SS} | — | 0.8 | V | SM bus enabled |
| DI20 | V _{IH} | Input High Voltage⁽²⁾ I/O pins: with Schmitt Trigger buffer | 0.8 V _{DD} | — | V _{DD} | V | |
| DI25 | | <u>MCLR</u> | 0.8 V _{DD} | — | V _{DD} | V | |
| DI26 | | OSC1 (in XT, HS and LP modes) | 0.7 V _{DD} | — | V _{DD} | V | |
| DI27 | | OSC1 (in RC mode) ⁽³⁾ | 0.9 V _{DD} | — | V _{DD} | V | |
| DI28 | | SDA, SCL | 0.7 V _{DD} | — | V _{DD} | V | SM bus disabled |
| DI29 | | SDA, SCL | 2.1 | — | V _{DD} | V | SM bus enabled |
| DI30 | ICNPU | CNxx Pull-up Current⁽²⁾ | 50 | 250 | 400 | μA | V _{DD} = 5V, V _{PIN} = V _{SS} |
| DI50 | I _{IL} | Input Leakage Current⁽²⁾⁽⁴⁾⁽⁵⁾ I/O ports | — | 0.01 | ±1 | μA | V _{SS} ≤ V _{PIN} ≤ V _{DD} , Pin at high impedance |
| DI51 | | Analog input pins | — | 0.50 | — | μA | V _{SS} ≤ V _{PIN} ≤ V _{DD} , Pin at high impedance |
| DI55 | | <u>MCLR</u> | — | 0.05 | ±5 | μA | V _{SS} ≤ V _{PIN} ≤ V _{DD} |
| DI56 | | OSC1 | — | 0.05 | ±5 | μA | V _{SS} ≤ V _{PIN} ≤ V _{DD} , XT, HS and LP Osc mode |

Note 1: Data in “Typ” column is at 5V, 25°C unless otherwise stated. Parameters are for design guidance only and are not tested.

2: These parameters are characterized but not tested in manufacturing.

3: In RC oscillator configuration, the OSC1/CLKI pin is a Schmitt Trigger input. It is not recommended that the dsPIC30F device be driven with an external clock while in RC mode.

4: The leakage current on the MCLR pin is strongly dependent on the applied voltage level. The specified levels represent normal operating conditions. Higher leakage current may be measured at different input voltages.

5: Negative current is defined as current sourced by the pin.

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TABLE 20-9: DC CHARACTERISTICS: I/O PIN OUTPUT SPECIFICATIONS

| DC CHARACTERISTICS | | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤ TA ≤ +85°C for Industrial -40°C ≤ TA ≤ +125°C for Extended | | | | |
|--------------------|--------|--|---|--------------------|------|-------|--|
| Param No. | Symbol | Characteristic | Min | Typ ⁽¹⁾ | Max | Units | Conditions |
| DO10 | VOL | Output Low Voltage⁽²⁾ I/O ports | — | — | 0.6 | V | IO _L = 8.5 mA, V _{DD} = 5V |
| | | | — | — | 0.15 | V | IO _L = 2.0 mA, V _{DD} = 3V |
| DO16 | | OSC2/CLKO | — | — | 0.6 | V | IO _L = 1.6 mA, V _{DD} = 5V |
| | | (RC or EC Osc mode) | — | — | 0.72 | V | IO _L = 2.0 mA, V _{DD} = 3V |
| DO20 | VOH | Output High Voltage⁽²⁾ I/O ports | V _{DD} - 0.7 | — | — | V | IO _H = -3.0 mA, V _{DD} = 5V |
| | | | V _{DD} - 0.2 | — | — | V | IO _H = -2.0 mA, V _{DD} = 3V |
| DO26 | | OSC2/CLKO | V _{DD} - 0.7 | — | — | V | IO _H = -1.3 mA, V _{DD} = 5V |
| | | (RC or EC Osc mode) | V _{DD} - 0.1 | — | — | V | IO _H = -2.0 mA, V _{DD} = 3V |
| DO50 | Cosc2 | Capacitive Loading Specs on Output Pins⁽²⁾ OSC2/SOSC2 pin | — | — | 15 | pF | In XTL, XT, HS and LP modes when external clock is used to drive OSC1. |
| DO56 | Cio | All I/O pins and OSC2 | — | — | 50 | pF | RC or EC Osc mode |
| DO58 | CB | SCL, SDA | — | — | 400 | pF | In I ² C mode |

Note 1: Data in "Typ" column is at 5V, 25°C unless otherwise stated. Parameters are for design guidance only and are not tested.

2: These parameters are characterized but not tested in manufacturing.

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FIGURE 20-1: LOW-VOLTAGE DETECT CHARACTERISTICS

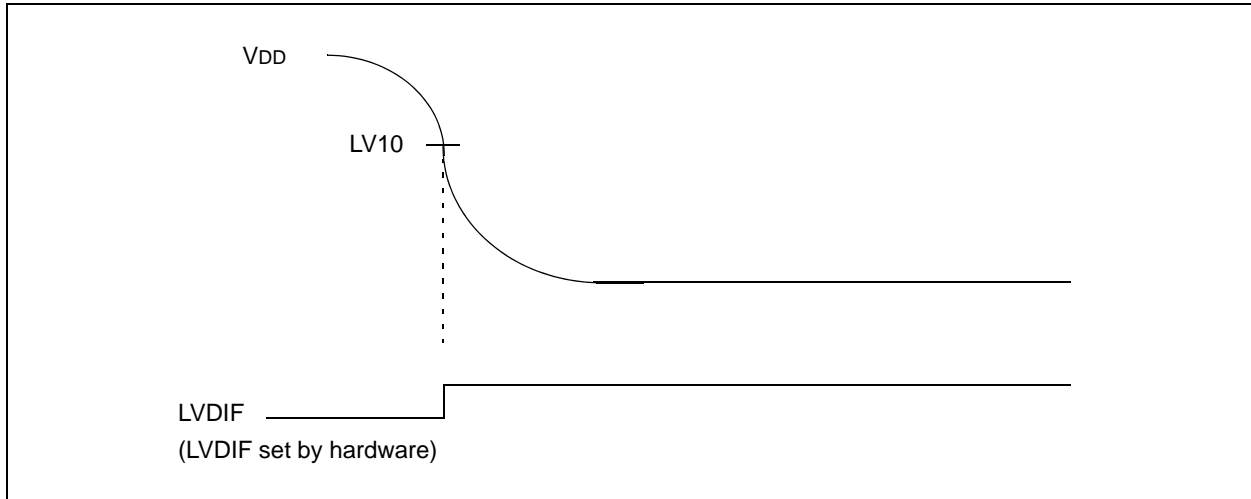


TABLE 20-10: ELECTRICAL CHARACTERISTICS: LVDL

| DC CHARACTERISTICS | | | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤ TA ≤ +85°C for Industrial -40°C ≤ TA ≤ +125°C for Extended | | | | |
|--------------------|--------|--|----------------------------|---|-----|------|-------|------------|
| Param No. | Symbol | Characteristic ⁽¹⁾ | | Min | Typ | Max | Units | Conditions |
| LV10 | VPLVD | LVDL Voltage on VDD transition high-to-low | LVDL = 0000 ⁽²⁾ | — | — | — | V | |
| | | | LVDL = 0001 ⁽²⁾ | — | — | — | V | |
| | | | LVDL = 0010 ⁽²⁾ | — | — | — | V | |
| | | | LVDL = 0011 ⁽²⁾ | — | — | — | V | |
| | | | LVDL = 0100 | 2.50 | — | 2.65 | V | |
| | | | LVDL = 0101 | 2.70 | — | 2.86 | V | |
| | | | LVDL = 0110 | 2.80 | — | 2.97 | V | |
| | | | LVDL = 0111 | 3.00 | — | 3.18 | V | |
| | | | LVDL = 1000 | 3.30 | — | 3.50 | V | |
| | | | LVDL = 1001 | 3.50 | — | 3.71 | V | |
| | | | LVDL = 1010 | 3.60 | — | 3.82 | V | |
| | | | LVDL = 1011 | 3.80 | — | 4.03 | V | |
| | | | LVDL = 1100 | 4.00 | — | 4.24 | V | |
| | | | LVDL = 1101 | 4.20 | — | 4.45 | V | |
| | | | LVDL = 1110 | 4.50 | — | 4.77 | V | |
| LV15 | VLVDIN | External LVD input pin threshold voltage | LVDL = 1111 | — | — | — | V | |

Note 1: These parameters are characterized but not tested in manufacturing.

2: These values not in usable operating range.

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FIGURE 20-2: BROWN-OUT RESET CHARACTERISTICS

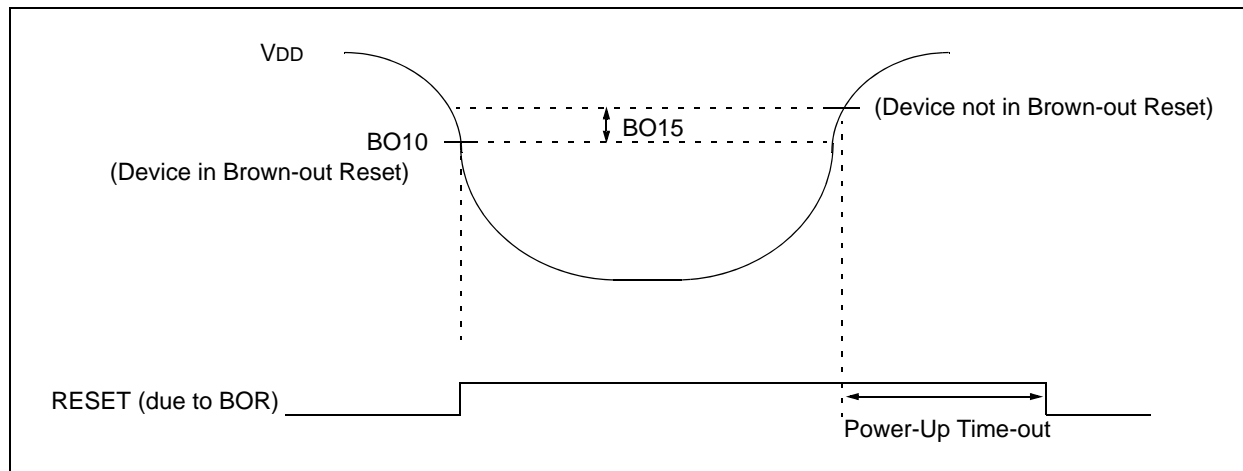


TABLE 20-11: ELECTRICAL CHARACTERISTICS: BOR

| DC CHARACTERISTICS | | | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤ TA ≤ +85°C for Industrial -40°C ≤ TA ≤ +125°C for Extended | | | | |
|--------------------|--------|--|--------------------------|---|--------------------|------|-------|------------------------|
| Param No. | Symbol | Characteristic | | Min | Typ ⁽¹⁾ | Max | Units | Conditions |
| BO10 | VBOR | BOR Voltage ⁽²⁾ on VDD transition high to low | BORV = 11 ⁽³⁾ | — | — | — | V | Not in operating range |
| | | | BORV = 10 | 2.6 | — | 2.71 | V | |
| | | | BORV = 01 | 4.1 | — | 4.4 | V | |
| | | | BORV = 00 | 4.58 | — | 4.73 | V | |
| BO15 | VBHYS | | | — | 5 | — | mV | |

Note 1: Data in “Typ” column is at 5V, 25°C unless otherwise stated. Parameters are for design guidance only and are not tested.

2: These parameters are characterized but not tested in manufacturing.

3: 11 values not in usable operating range.

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TABLE 20-12: DC CHARACTERISTICS: PROGRAM AND EEPROM

| DC CHARACTERISTICS | | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤ TA ≤ +85°C for Industrial -40°C ≤ TA ≤ +125°C for Extended | | | | |
|---|--------|--------------------------|---|--------------------|-----|-------|---|
| Param No. | Symbol | Characteristic | Min | Typ ⁽¹⁾ | Max | Units | Conditions |
| Data EEPROM Memory⁽²⁾ | | | | | | | |
| D120 | ED | Byte Endurance | 100K | 1M | — | E/W | -40° C ≤ TA ≤ +85°C |
| D121 | VDRW | VDD for Read/Write | V _{MIN} | — | 5.5 | V | Using EECON to Read/Write V _{MIN} = Minimum operating voltage |
| D122 | TDEW | Erase/Write Cycle Time | 0.8 | 2 | 2.6 | ms | RTSP |
| D123 | TRETD | Characteristic Retention | 40 | 100 | — | Year | Provided no other specifications are violated |
| D124 | IDEW | IDD During Programming | — | 10 | 30 | mA | Row Erase |
| Program Flash Memory⁽²⁾ | | | | | | | |
| D130 | EP | Cell Endurance | 10K | 100K | — | E/W | -40° C ≤ TA ≤ +85°C |
| D131 | VPR | VDD for Read | V _{MIN} | — | 5.5 | V | V _{MIN} = Minimum operating voltage |
| D132 | VEB | VDD for Bulk Erase | 4.5 | — | 5.5 | V | |
| D133 | VPEW | VDD for Erase/Write | 3.0 | — | 5.5 | V | |
| D134 | TPEW | Erase/Write Cycle Time | 0.8 | 2 | 2.6 | ms | RTSP |
| D135 | TRETD | Characteristic Retention | 40 | 100 | — | Year | Provided no other specifications are violated |
| D137 | IPEW | IDD During Programming | — | 10 | 30 | mA | Row Erase |
| D138 | IEB | IDD During Programming | — | 10 | 30 | mA | Bulk Erase |

Note 1: Data in “Typ” column is at 5V, 25°C unless otherwise stated.

2: These parameters are characterized but not tested in manufacturing.

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20.2 AC Characteristics and Timing Parameters

The information contained in this section defines dsPIC30F AC characteristics and timing parameters.

TABLE 20-13: TEMPERATURE AND VOLTAGE SPECIFICATIONS – AC

| | |
|--------------------|---|
| AC CHARACTERISTICS | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) |
| | Operating temperature $-40^{\circ}\text{C} \leq T_A \leq +85^{\circ}\text{C}$ for Industrial $-40^{\circ}\text{C} \leq T_A \leq +125^{\circ}\text{C}$ for Extended Operating voltage V_{DD} range as described in Section 20.1 “DC Characteristics” . |

FIGURE 20-3: LOAD CONDITIONS FOR DEVICE TIMING SPECIFICATIONS

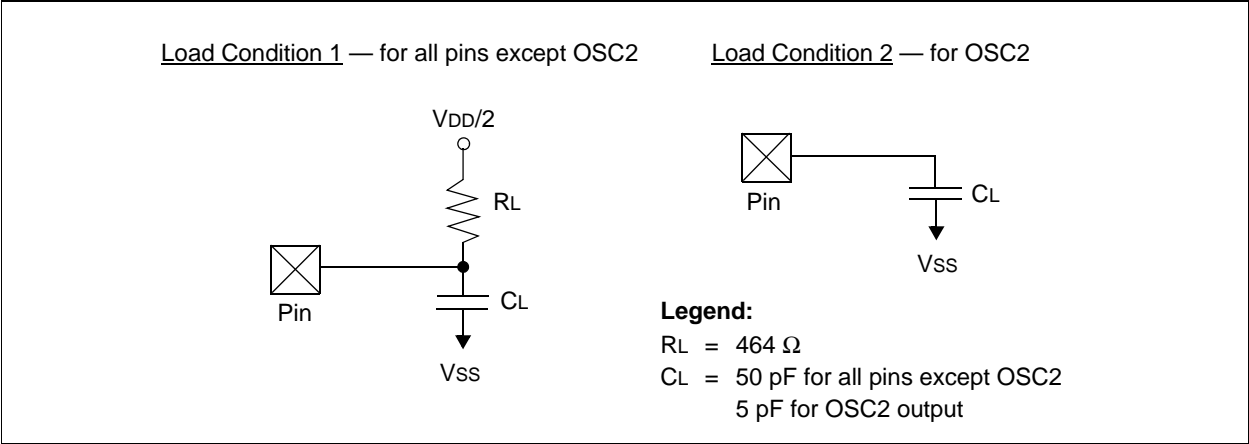
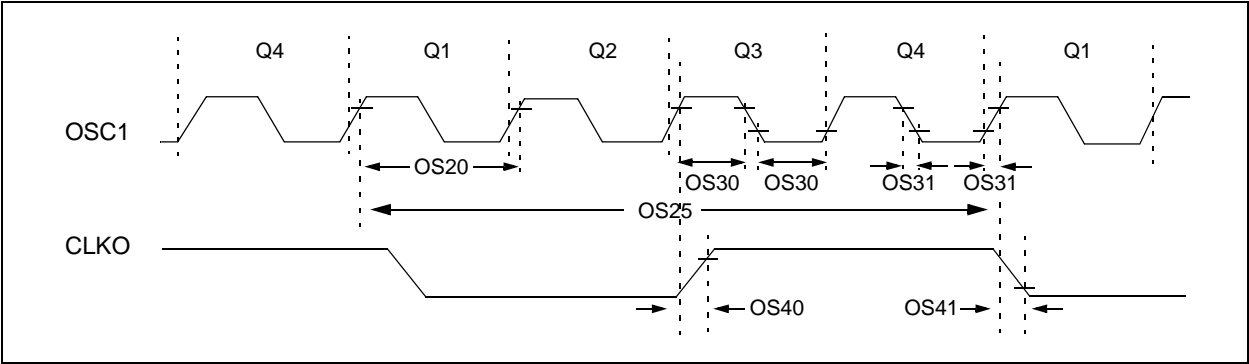


FIGURE 20-4: EXTERNAL CLOCK TIMING



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TABLE 20-14: EXTERNAL CLOCK TIMING REQUIREMENTS

| AC CHARACTERISTICS | | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤ TA ≤ +85°C for Industrial -40°C ≤ TA ≤ +125°C for Extended | | | | |
|--------------------|------------|---|---|--------------------|------|-------|------------------------------------|
| Param No. | Symbol | Characteristic | Min | Typ ⁽¹⁾ | Max | Units | Conditions |
| OS10 | Fosc | External CLKN Frequency ⁽²⁾ (External clocks allowed only in EC mode) | DC | — | 40 | MHz | EC |
| | | | 4 | — | 10 | MHz | EC with 4x PLL |
| | | | 4 | — | 10 | MHz | EC with 8x PLL |
| | | | 4 | — | 7.5 | MHz | EC with 16x PLL |
| | | Oscillator Frequency ⁽²⁾ | DC | — | 4 | MHz | RC |
| | | | 0.4 | — | 4 | MHz | XTL |
| | | | 4 | — | 10 | MHz | XT |
| | | | 4 | — | 10 | MHz | XT with 4x PLL |
| | | | 4 | — | 10 | MHz | XT with 8x PLL |
| | | | 4 | — | 7.5 | MHz | XT with 16x PLL |
| | | | 10 | — | 25 | MHz | HS |
| | | | 10 | — | 20 | MHz | HS/2 with 4x PLL |
| | | | 10 | — | 20 | MHz | HS/2 with 8x PLL |
| | | | 10 | — | 15 | MHz | HS/2 with 16x PLL |
| | | | 12 | — | 25 | MHz | HS/3 with 4x PLL |
| | | | 12 | — | 25 | MHz | HS/3 with 8x PLL |
| | | | 12 | — | 22.5 | MHz | HS/3 with 16x PLL |
| | | | 31 | — | 33 | kHz | LP |
| | | | — | 7.37 | — | MHz | FRC internal |
| | | | — | 7.37 | — | MHz | FRC internal w/4x PLL |
| | | | — | 7.37 | — | MHz | FRC internal w/8x PLL |
| | | | — | 7.37 | — | MHz | FRC internal w/16x PLL |
| | | | — | 512 | — | kHz | LPRC internal |
| OS20 | Tosc | Tosc = 1/Fosc | — | — | — | — | See parameter OS10 for Fosc value |
| OS25 | Tcy | Instruction Cycle Time ⁽²⁾⁽³⁾ | 33 | — | DC | ns | See Table 20-17 |
| OS30 | TosL, TosH | External Clock ⁽²⁾ in (OSC1) High or Low Time | .45 x TOSC | — | — | ns | EC |
| OS31 | TosR, TosF | External Clock ⁽²⁾ in (OSC1) Rise or Fall Time | — | — | 20 | ns | EC |
| OS40 | TckR | CLKO Rise Time ⁽²⁾⁽⁴⁾ | — | — | — | ns | See parameter DO31 |
| OS41 | TckF | CLKO Fall Time ⁽²⁾⁽⁴⁾ | — | — | — | ns | See parameter DO32 |

Note 1: Data in “Typ” column is at 5V, 25°C unless otherwise stated. Parameters are for design guidance only and are not tested.

2: These parameters are characterized but not tested in manufacturing.

3: Instruction cycle period (Tcy) equals four times the input oscillator time-base period. All specified values are based on characterization data for that particular oscillator type under standard operating conditions with the device executing code. Exceeding these specified limits may result in an unstable oscillator operation and/or higher than expected current consumption. All devices are tested to operate at “min.” values with an external clock applied to the OSC1/CLKI pin. When an external clock input is used, the “Max.” cycle time limit is “DC” (no clock) for all devices.

4: Measurements are taken in EC or ERC modes. The CLKO signal is measured on the OSC2 pin. CLKO is low for the Q1-Q2 period (1/2 Tcy) and high for the Q3-Q4 period (1/2 Tcy).

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TABLE 20-15: PLL CLOCK TIMING SPECIFICATIONS (VDD = 2.5 TO 5.5 V)

| AC CHARACTERISTICS | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤ TA ≤ +85°C for Industrial -40°C ≤ TA ≤ +125°C for Extended | | | | | |
|--------------------|--------|---|------------------|--------------------|---------------------|-------|-----------------------------------|
| Param No. | Symbol | Characteristic ⁽¹⁾ | Min | Typ ⁽²⁾ | Max | Units | Conditions |
| OS50 | FPLLI | PLL Input Frequency Range ⁽²⁾ | 4 | — | 10 | MHz | EC with 4x PLL |
| | | | 4 | — | 10 | MHz | EC with 8x PLL |
| | | | 4 | — | 7.5 ⁽⁴⁾ | MHz | EC with 16x PLL |
| | | | 4 | — | 10 | MHz | XT with 4x PLL |
| | | | 4 | — | 10 | MHz | XT with 8x PLL |
| | | | 4 | — | 7.5 ⁽⁴⁾ | MHz | XT with 16x PLL |
| | | | 5 ⁽³⁾ | — | 10 | MHz | HS/2 with 4x PLL |
| | | | 5 ⁽³⁾ | — | 10 | MHz | HS/2 with 8x PLL |
| | | | 5 ⁽³⁾ | — | 7.5 ⁽⁴⁾ | MHz | HS/2 with 16x PLL |
| | | | 4 | — | 8.33 ⁽³⁾ | MHz | HS/3 with 4x PLL |
| | | | 4 | — | 8.33 ⁽³⁾ | MHz | HS/3 with 8x PLL |
| | | | 4 | — | 7.5 ⁽⁴⁾ | MHz | HS/3 with 16x PLL |
| OS51 | FSYS | On-Chip PLL Output ⁽²⁾ | 16 | — | 120 | MHz | EC, XT, HS/2, HS/3 modes with PLL |
| OS52 | TLOC | PLL Start-up Time (Lock Time) | — | 20 | 50 | μs | |

Note 1: These parameters are characterized but not tested in manufacturing.

2: Data in "Typ" column is at 5V, 25°C unless otherwise stated. Parameters are for design guidance only and are not tested.

3: Limited by oscillator frequency range.

4: Limited by device operating frequency range.

TABLE 20-16: PLL JITTER

| AC CHARACTERISTICS | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤ TA ≤ +85°C for Industrial -40°C ≤ TA ≤ +125°C for Extended | | | | | |
|--------------------|----------------|---|--------------------|-------|-------|---------------------|-------------------|
| Param No. | Characteristic | Min | Typ ⁽¹⁾ | Max | Units | Conditions | |
| OS61 | x4 PLL | — | 0.251 | 0.413 | % | -40°C ≤ TA ≤ +85°C | VDD = 3.0 to 3.6V |
| | | — | 0.251 | 0.413 | % | -40°C ≤ TA ≤ +125°C | VDD = 3.0 to 3.6V |
| | | — | 0.256 | 0.47 | % | -40°C ≤ TA ≤ +85°C | VDD = 4.5 to 5.5V |
| | | — | 0.256 | 0.47 | % | -40°C ≤ TA ≤ +125°C | VDD = 4.5 to 5.5V |
| | x8 PLL | — | 0.355 | 0.584 | % | -40°C ≤ TA ≤ +85°C | VDD = 3.0 to 3.6V |
| | | — | 0.355 | 0.584 | % | -40°C ≤ TA ≤ +125°C | VDD = 3.0 to 3.6V |
| | | — | 0.362 | 0.664 | % | -40°C ≤ TA ≤ +85°C | VDD = 4.5 to 5.5V |
| | | — | 0.362 | 0.664 | % | -40°C ≤ TA ≤ +125°C | VDD = 4.5 to 5.5V |
| | x16 PLL | — | 0.67 | 0.92 | % | -40°C ≤ TA ≤ +85°C | VDD = 3.0 to 3.6V |
| | | — | 0.632 | 0.956 | % | -40°C ≤ TA ≤ +85°C | VDD = 4.5 to 5.5V |
| | | — | 0.632 | 0.956 | % | -40°C ≤ TA ≤ +125°C | VDD = 4.5 to 5.5V |
| | | — | 0.632 | 0.956 | % | -40°C ≤ TA ≤ +125°C | VDD = 4.5 to 5.5V |

Note 1: These parameters are characterized but not tested in manufacturing.

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TABLE 20-17: INTERNAL CLOCK TIMING EXAMPLES

| Clock Oscillator Mode | Fosc (MHz) ⁽¹⁾ | Tcy (μsec) ⁽²⁾ | MIPS ⁽³⁾ w/o PLL | MIPS ⁽³⁾ w PLL x4 | MIPS ⁽³⁾ w PLL x8 | MIPS ⁽³⁾ w PLL x16 |
|-----------------------|---------------------------|---------------------------|-----------------------------|------------------------------|------------------------------|-------------------------------|
| EC | 0.200 | 20.0 | 0.05 | — | — | — |
| | 4 | 1.0 | 1.0 | 4.0 | 8.0 | 16.0 |
| | 10 | 0.4 | 2.5 | 10.0 | 20.0 | — |
| | 25 | 0.16 | 6.25 | — | — | — |
| XT | 4 | 1.0 | 1.0 | 4.0 | 8.0 | 16.0 |
| | 10 | 0.4 | 2.5 | 10.0 | 20.0 | — |

Note 1: Assumption: Oscillator Postscaler is divide by 1.

Note 2: Instruction Execution Cycle Time: Tcy = 1/MIPS.

Note 3: Instruction Execution Frequency: MIPS = (Fosc * PLLx)/4 [since there are 4 Q clocks per instruction cycle].

TABLE 20-18: AC CHARACTERISTICS: INTERNAL FRC ACCURACY

| AC CHARACTERISTICS | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤TA ≤+85°C for Industrial | | | | | |
|--------------------|--|--|--|--|--|--|--|
|--------------------|--|--|--|--|--|--|--|

Note 1: Frequency calibrated at 7.372 MHz ±2%, 25°C and 5V. TUN bits (OSCCON<3:0>) can be used to compensate for temperature drift.

TABLE 20-19: AC CHARACTERISTICS: INTERNAL LPRC ACCURACY

| AC CHARACTERISTICS | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤TA ≤+85°C for Industrial -40°C ≤TA ≤+125°C for Extended | | | | |
|--------------------|---------------------------------------|--|-----|-----|-------|------------------|
| Param No. | Characteristic | Min | Typ | Max | Units | Conditions |
| | LPRC @ Freq. = 512 kHz ⁽¹⁾ | | | | | |
| OS65A | | -50 | — | +50 | % | VDD = 5.0V, ±10% |
| OS65B | | -60 | — | +60 | % | VDD = 3.3V, ±10% |
| OS65C | | -70 | — | +70 | % | VDD = 2.5V |

Note 1: Change of LPRC frequency as VDD changes.

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FIGURE 20-5: CLKO AND I/O TIMING CHARACTERISTICS

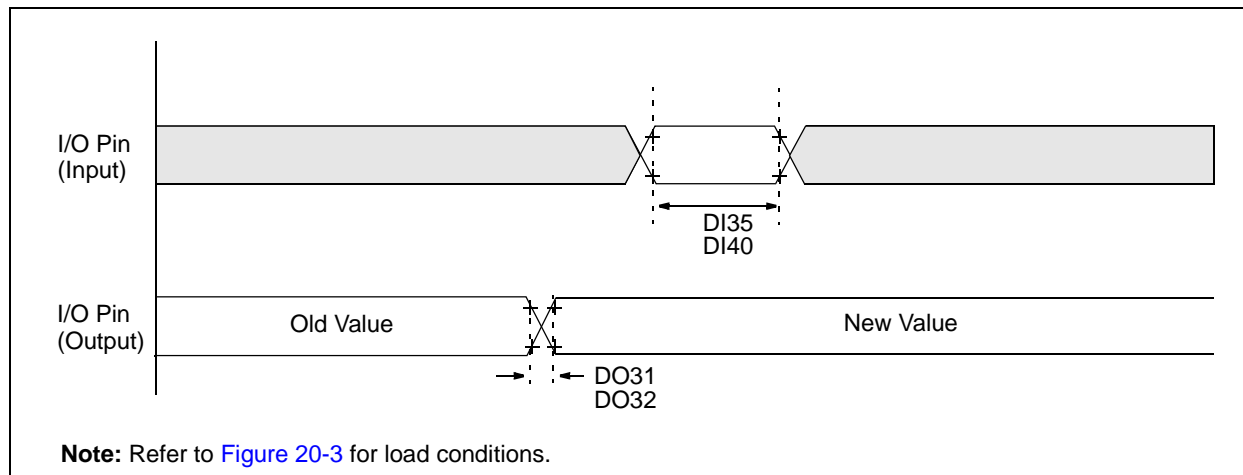


TABLE 20-20: CLKO AND I/O TIMING REQUIREMENTS

| AC CHARACTERISTICS | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤ TA ≤ +85°C for Industrial -40°C ≤ TA ≤ +125°C for Extended | | | | | |
|--------------------|--------|---|-------|--------------------|-----|-------|------------|
| Param No. | Symbol | Characteristic ⁽¹⁾⁽²⁾⁽³⁾ | Min | Typ ⁽⁴⁾ | Max | Units | Conditions |
| DO31 | TiOR | Port output rise time | — | 7 | 20 | ns | |
| DO32 | TiOF | Port output fall time | — | 7 | 20 | ns | |
| DI35 | TINP | INTx pin high or low time (output) | 20 | — | — | ns | |
| DI40 | TRBP | CNx high or low time (input) | 2 TCY | — | — | ns | |

- Note 1:** These parameters are asynchronous events not related to any internal clock edges
Note 2: Measurements are taken in RC mode and EC mode where CLKO output is 4 x TOSC.
Note 3: These parameters are characterized but not tested in manufacturing.
Note 4: Data in “Typ” column is at 5V, 25°C unless otherwise stated.

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FIGURE 20-6: RESET, WATCHDOG TIMER, OSCILLATOR START-UP TIMER AND POWER-UP TIMER TIMING CHARACTERISTICS

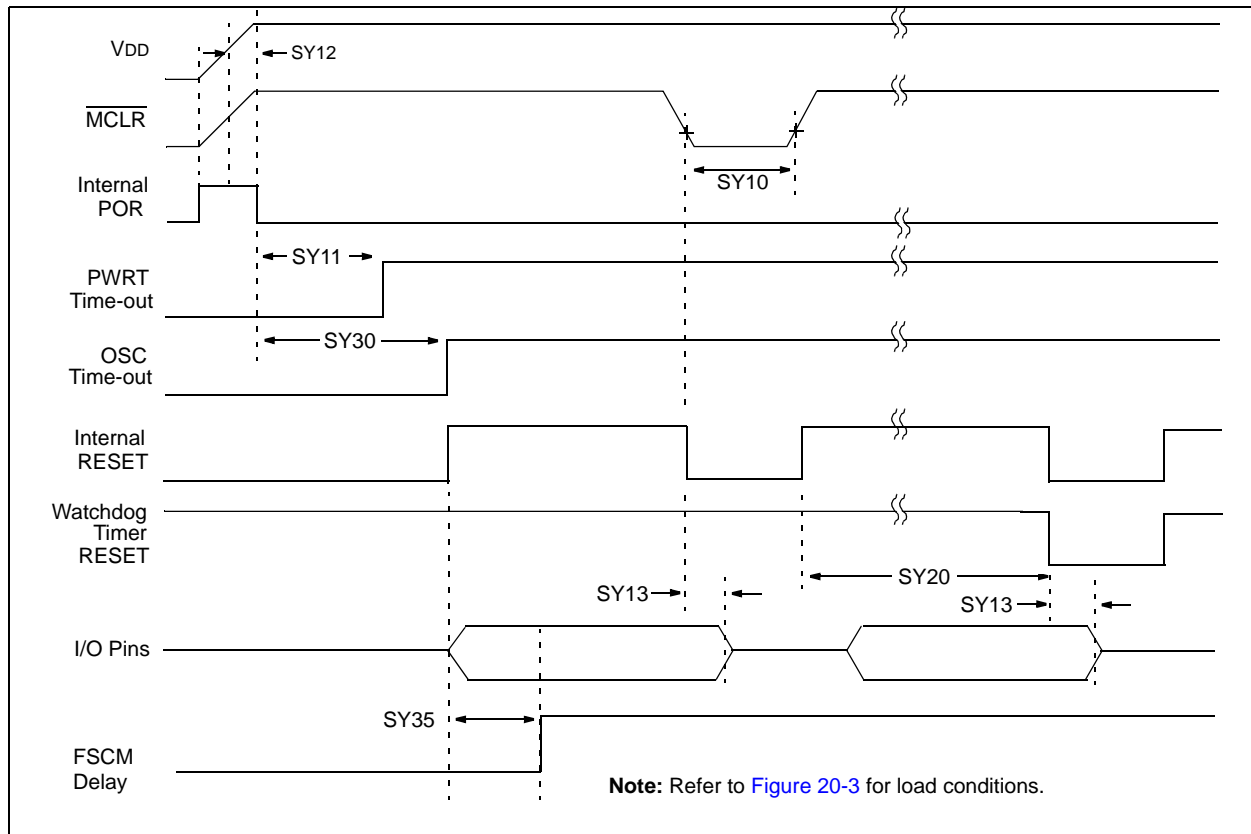


TABLE 20-21: RESET, WATCHDOG TIMER, OSCILLATOR START-UP TIMER, POWER-UP TIMER AND BROWN-OUT RESET TIMING REQUIREMENTS

| AC CHARACTERISTICS | | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤ TA ≤ +85°C for Industrial -40°C ≤ TA ≤ +125°C for Extended | | | | |
|--------------------|-------------------------|--|---|--------------------|-------------------|----------------|--|
| Param No. | Symbol | Characteristic ⁽¹⁾ | Min | Typ ⁽²⁾ | Max | Units | Conditions |
| SY10 | TmCL | MCLR Pulse Width (low) | 2 | — | — | μs | -40°C to +85°C |
| SY11 | TPWRT | Power-up Timer Period | 2 10 43 | 4 16 64 | 8 32 128 | ms | -40°C to +85°C, VDD = 5V User programmable |
| SY12 | TPOR | Power On Reset Delay | 3 | 10 | 30 | μs | -40°C to +85°C |
| SY13 | TIOZ | I/O high impedance from MCLR Low or Watchdog Timer Reset | — | 0.8 | 1.0 | μs | |
| SY20 | TWDT1 TWDT2 TWDT3 | Watchdog Timer Time-out Period (No Prescaler) | 1.1 1.2 1.3 | 2.0 2.0 2.0 | 6.6 5.0 4.0 | ms ms ms | VDD = 2.5V VDD = 3.3V, ±10% VDD = 5V, ±10% |
| SY25 | TBOR | Brown-out Reset Pulse Width ⁽³⁾ | 100 | — | — | μs | VDD ≤ VBOR (D034) |
| SY30 | TOST | Oscillation Start-up Timer Period | — | 1024 TOSC | — | — | TOSC = OSC1 period |
| SY35 | TFSCM | Fail-Safe Clock Monitor Delay | — | 500 | 900 | μs | -40°C to +85°C |

Note 1: These parameters are characterized but not tested in manufacturing.

Note 2: Data in "Typ" column is at 5V, 25°C unless otherwise stated.

Note 3: Refer to Figure 20-2 and Table 20-11 for BOR.

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FIGURE 20-7: BAND GAP START-UP TIME CHARACTERISTICS

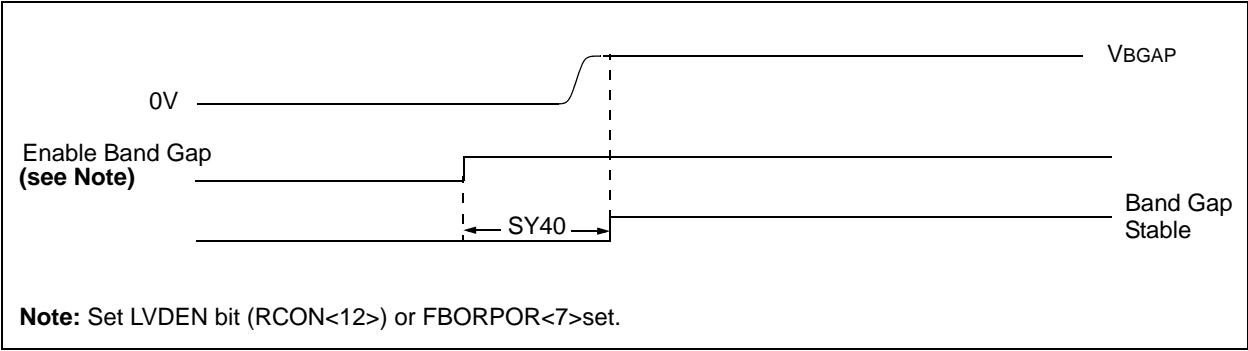


TABLE 20-22: BAND GAP START-UP TIME REQUIREMENTS

| AC CHARACTERISTICS | | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤TA ≤+85°C for Industrial -40°C ≤TA ≤+125°C for Extended | | | | |
|--------------------|--------|-------------------------------|---|--------------------|-----|-------|--|
| Param No. | Symbol | Characteristic ⁽¹⁾ | Min | Typ ⁽²⁾ | Max | Units | Conditions |
| SY40 | TBGAP | Band Gap Start-up Time | — | 40 | 65 | μs | Defined as the time between the instant that the band gap is enabled and the moment that the band gap reference voltage is stable. RCON<13> bit |

- Note 1:** These parameters are characterized but not tested in manufacturing.
Note 2: Data in “Typ” column is at 5V, 25°C unless otherwise stated.

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FIGURE 20-8: TYPE A, B AND C TIMER EXTERNAL CLOCK TIMING CHARACTERISTICS

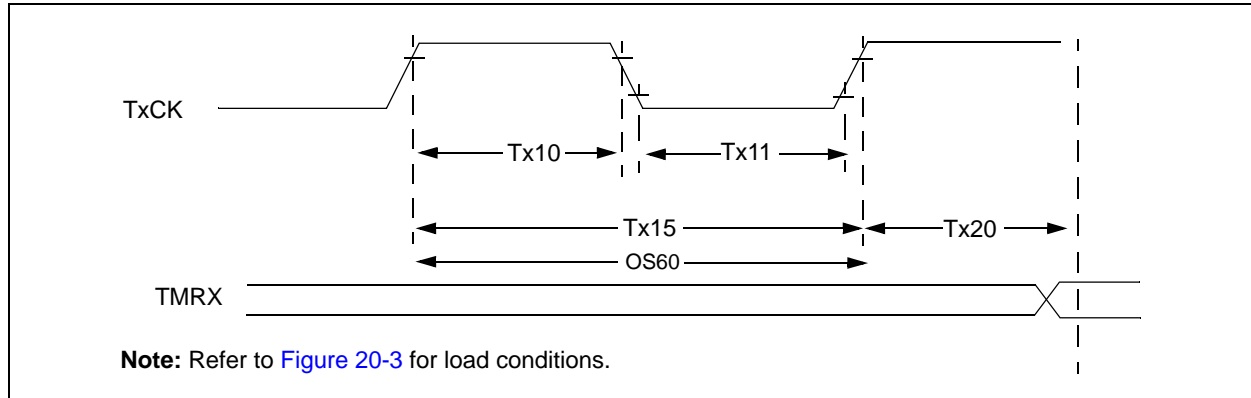


TABLE 20-23: TYPE A TIMER (TIMER1) EXTERNAL CLOCK TIMING REQUIREMENTS

| AC CHARACTERISTICS | | | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤TA ≤+85°C for Industrial -40°C ≤TA ≤+125°C for Extended | | | | |
|--------------------|-----------------------|--|-----------------------------|--|-----|---------------------|-------|---------------------------------------|
| Param No. | Symbol | Characteristic | | Min | Typ | Max | Units | Conditions |
| TA10 | T _{TXH} | TxCK High Time | Synchronous, no prescaler | 0.5 T _{CY} + 20 | — | — | ns | Must also meet parameter TA15 |
| | | | Synchronous, with prescaler | 10 | — | — | ns | |
| | | | Asynchronous | 10 | — | — | ns | |
| TA11 | T _{TXL} | TxCK Low Time | Synchronous, no prescaler | 0.5 T _{CY} + 20 | — | — | ns | Must also meet parameter TA15 |
| | | | Synchronous, with prescaler | 10 | — | — | ns | |
| | | | Asynchronous | 10 | — | — | ns | |
| TA15 | T _{TXP} | TxCK Input Period | Synchronous, no prescaler | T _{CY} + 10 | — | — | ns | N = prescale value (1, 8, 64, 256) |
| | | | Synchronous, with prescaler | Greater of: 20 ns or (T _{CY} + 40)/N | — | — | — | |
| | | | Asynchronous | 20 | — | — | ns | |
| OS60 | F _{t1} | SOSC1/T1CK oscillator input frequency range (oscillator enabled by setting bit TCS (T1CON, bit 1)) | | DC | — | 50 | kHz | |
| TA20 | T _{CKEXTMRL} | Delay from External TxCK Clock Edge to Timer Increment | | 0.5 T _{CY} | — | 1.5 T _{CY} | — | |

Note: Timer1 is a Type A.

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TABLE 20-24: TYPE B TIMER (TIMER2 AND TIMER4) EXTERNAL CLOCK TIMING REQUIREMENTS

| AC CHARACTERISTICS | | | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤TA ≤+85°C for Industrial -40°C ≤TA ≤+125°C for Extended | | | | |
|--------------------|-----------|--|-----------------------------|--|-----|---------|-------|---------------------------------------|
| Param No. | Symbol | Characteristic | | Min | Typ | Max | Units | Conditions |
| TB10 | TtxH | TxCK High Time | Synchronous, no prescaler | 0.5 Tcy + 20 | — | — | ns | Must also meet parameter TB15 |
| | | | Synchronous, with prescaler | 10 | — | — | ns | |
| TB11 | TtxL | TxCK Low Time | Synchronous, no prescaler | 0.5 Tcy + 20 | — | — | ns | Must also meet parameter TB15 |
| | | | Synchronous, with prescaler | 10 | — | — | ns | |
| TB15 | TtxP | TxCK Input Period | Synchronous, no prescaler | Tcy + 10 | — | — | ns | N = prescale value (1, 8, 64, 256) |
| | | | Synchronous, with prescaler | Greater of: 20 ns or (Tcy + 40)/N | | | | |
| TB20 | TCKEXTMRL | Delay from External TxCK Clock Edge to Timer Increment | | 0.5 Tcy | — | 1.5 Tcy | — | |

Note: Timer2 and Timer4 are Type B.

TABLE 20-25: TYPE C TIMER (TIMER3 AND TIMER5) EXTERNAL CLOCK TIMING REQUIREMENTS

| AC CHARACTERISTICS | | | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤TA ≤+85°C for Industrial -40°C ≤TA ≤+125°C for Extended | | | | |
|--------------------|-----------|--|-----------------------------|---|-----|---------|-------|------------------------------------|
| Param No. | Symbol | Characteristic | | Min | Typ | Max | Units | Conditions |
| TC10 | TtxH | TxCK High Time | Synchronous | 0.5 TCY + 20 | — | — | ns | Must also meet parameter TC15 |
| TC11 | TtxL | TxCK Low Time | Synchronous | 0.5 TCY + 20 | — | — | ns | Must also meet parameter TC15 |
| TC15 | TtxP | TxCK Input Period | Synchronous, no prescaler | TCY + 10 | — | — | ns | N = prescale value (1, 8, 64, 256) |
| | | | Synchronous, with prescaler | Greater of: 20 ns or (TCY + 40)/N | | | | |
| TC20 | TCKEXTMRL | Delay from External TxCK Clock Edge to Timer Increment | | 0.5 TCY | — | 1.5 TCY | — | |

Note: Timer3 and Timer5 are Type C.

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FIGURE 20-9: INPUT CAPTURE (CAPx) TIMING CHARACTERISTICS

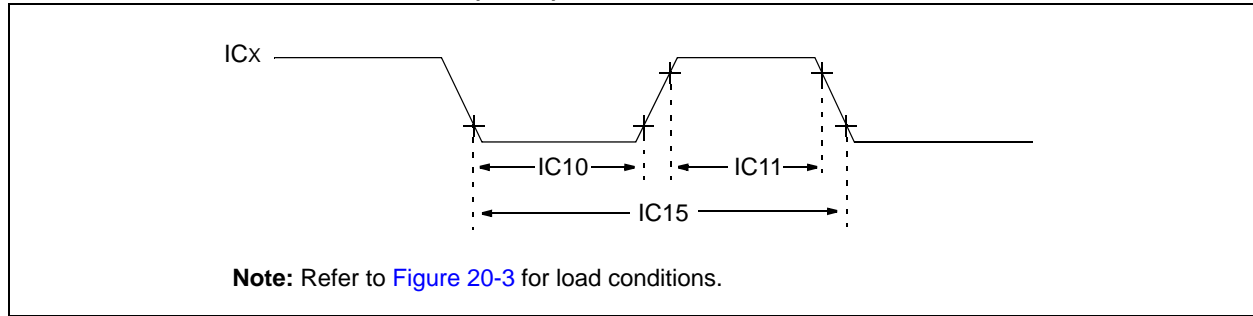


TABLE 20-26: INPUT CAPTURE TIMING REQUIREMENTS

| AC CHARACTERISTICS | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature $-40^{\circ}\text{C} \leq T_A \leq +85^{\circ}\text{C}$ for Industrial $-40^{\circ}\text{C} \leq T_A \leq +125^{\circ}\text{C}$ for Extended | | | | | |
|--------------------|--------|---|----------------|---------------------|-----|-------|-------------------------------|
| Param No. | Symbol | Characteristic ⁽¹⁾ | | Min | Max | Units | Conditions |
| IC10 | TccL | ICx Input Low Time | No Prescaler | $0.5 T_{CY} + 20$ | — | ns | |
| | | | With Prescaler | 10 | — | ns | |
| IC11 | TccH | ICx Input High Time | No Prescaler | $0.5 T_{CY} + 20$ | — | ns | |
| | | | With Prescaler | 10 | — | ns | |
| IC15 | TccP | ICx Input Period | | $(2 T_{CY} + 40)/N$ | — | ns | N = prescale value (1, 4, 16) |

Note 1: These parameters are characterized but not tested in manufacturing.

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FIGURE 20-10: OUTPUT COMPARE MODULE (OCx) TIMING CHARACTERISTICS

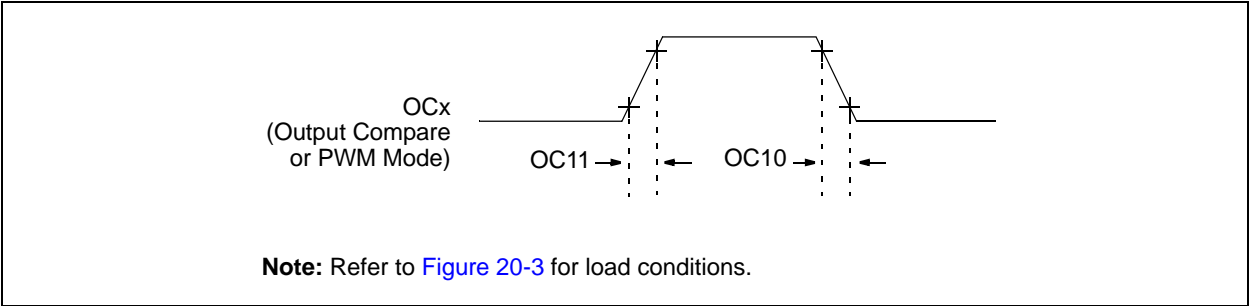


TABLE 20-27: OUTPUT COMPARE MODULE TIMING REQUIREMENTS

| AC CHARACTERISTICS | | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤TA ≤+85°C for Industrial -40°C ≤TA ≤+125°C for Extended | | | | |
|--------------------|--------|-------------------------------|---|--------------------|-----|-------|------------------------------------|
| Param No. | Symbol | Characteristic ⁽¹⁾ | Min | Typ ⁽²⁾ | Max | Units | Conditions |
| OC10 | TccF | OCx Output Fall Time | — | — | — | ns | See Parameter DO32 |
| OC11 | TccR | OCx Output Rise Time | — | — | — | ns | See Parameter DO31 |

- Note 1:** These parameters are characterized but not tested in manufacturing.
- Note 2:** Data in “Typ” column is at 5V, 25°C unless otherwise stated. Parameters are for design guidance only and are not tested.

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FIGURE 20-11: OC/PWM MODULE TIMING CHARACTERISTICS

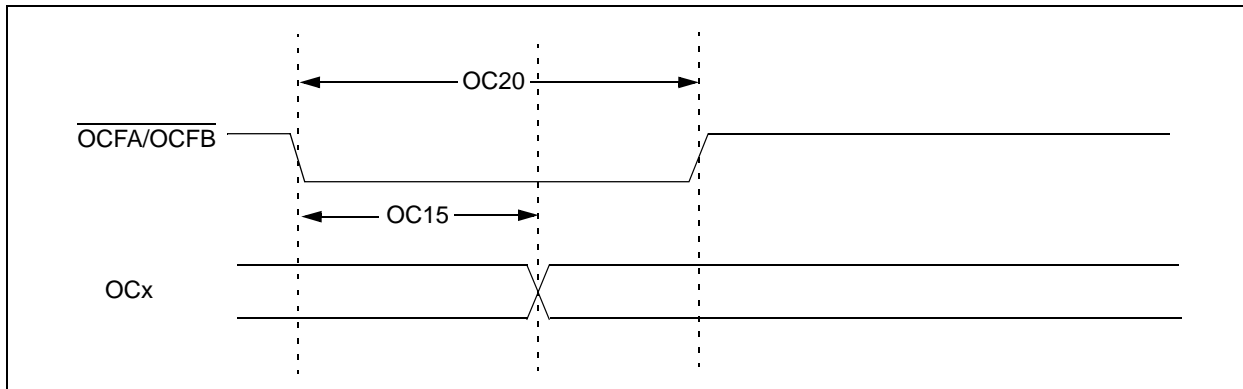


TABLE 20-28: SIMPLE OC/PWM MODE TIMING REQUIREMENTS

| AC CHARACTERISTICS | | | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤ TA ≤ +85°C for Industrial -40°C ≤ TA ≤ +125°C for Extended | | | |
|--------------------|--------|-------------------------------|-----|---|-----|-------|------------|
| Param No. | Symbol | Characteristic ⁽¹⁾ | Min | Typ ⁽²⁾ | Max | Units | Conditions |
| OC15 | TFD | Fault Input to PWM I/O Change | — | — | 50 | ns | |
| OC20 | TFLT | Fault Input Pulse Width | 50 | — | — | ns | |

Note 1: These parameters are characterized but not tested in manufacturing.

2: Data in “Typ” column is at 5V, 25°C unless otherwise stated. Parameters are for design guidance only and are not tested.

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FIGURE 20-12: SPI MODULE MASTER MODE (CKE = 0) TIMING CHARACTERISTICS

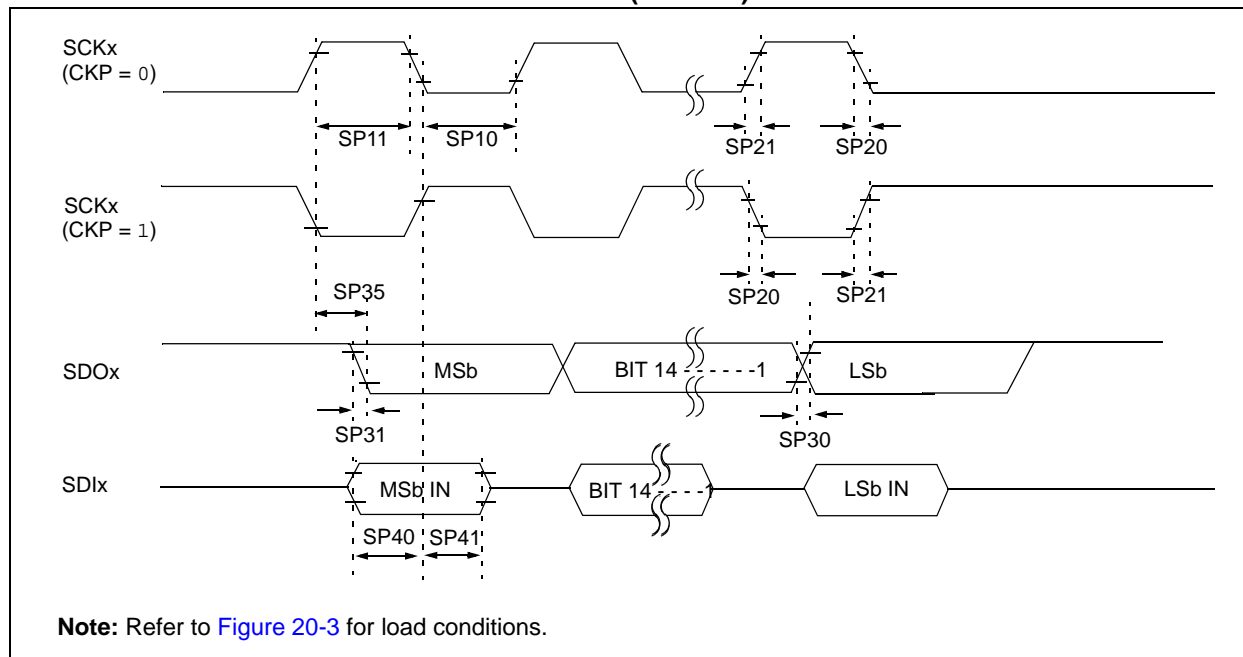


TABLE 20-29: SPI MASTER MODE (CKE = 0) TIMING REQUIREMENTS

| AC CHARACTERISTICS | | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤ TA ≤ +85°C for Industrial -40°C ≤ TA ≤ +125°C for Extended | | | | |
|--------------------|-----------------------|--|---|--------------------|-----|-------|------------------------------------|
| Param No. | Symbol | Characteristic ⁽¹⁾ | Min | Typ ⁽²⁾ | Max | Units | Conditions |
| SP10 | TscL | SCKx Output Low Time ⁽³⁾ | Tcy/2 | — | — | ns | — |
| SP11 | TscH | SCKx Output High Time ⁽³⁾ | Tcy/2 | — | — | ns | — |
| SP20 | TscF | SCKx Output Fall Time ⁽⁴⁾ | — | — | — | ns | See parameter DO32 |
| SP21 | TscR | SCKx Output Rise Time ⁽⁴⁾ | — | — | — | ns | See parameter DO31 |
| SP30 | TdoF | SDOx Data Output Fall Time ⁽⁴⁾ | — | — | — | ns | See parameter DO32 |
| SP31 | TdoR | SDOx Data Output Rise Time ⁽⁴⁾ | — | — | — | ns | See parameter DO31 |
| SP35 | Tsch2doV, TscL2doV | SDOx Data Output Valid after SCKx Edge | — | — | 30 | ns | — |
| SP40 | TdiV2scH, TdiV2scL | Setup Time of SDIx Data Input to SCKx Edge | 20 | — | — | ns | — |
| SP41 | Tsch2diL, TscL2diL | Hold Time of SDIx Data Input to SCKx Edge | 20 | — | — | ns | — |

- Note 1:** These parameters are characterized but not tested in manufacturing.
- Note 2:** Data in “Typ” column is at 5V, 25°C unless otherwise stated. Parameters are for design guidance only and are not tested.
- Note 3:** The minimum clock period for SCK is 100 ns. Therefore, the clock generated in Master mode must not violate this specification.
- Note 4:** Assumes 50 pF load on all SPI pins.

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FIGURE 20-13: SPI MODULE MASTER MODE (CKE = 1) TIMING CHARACTERISTICS

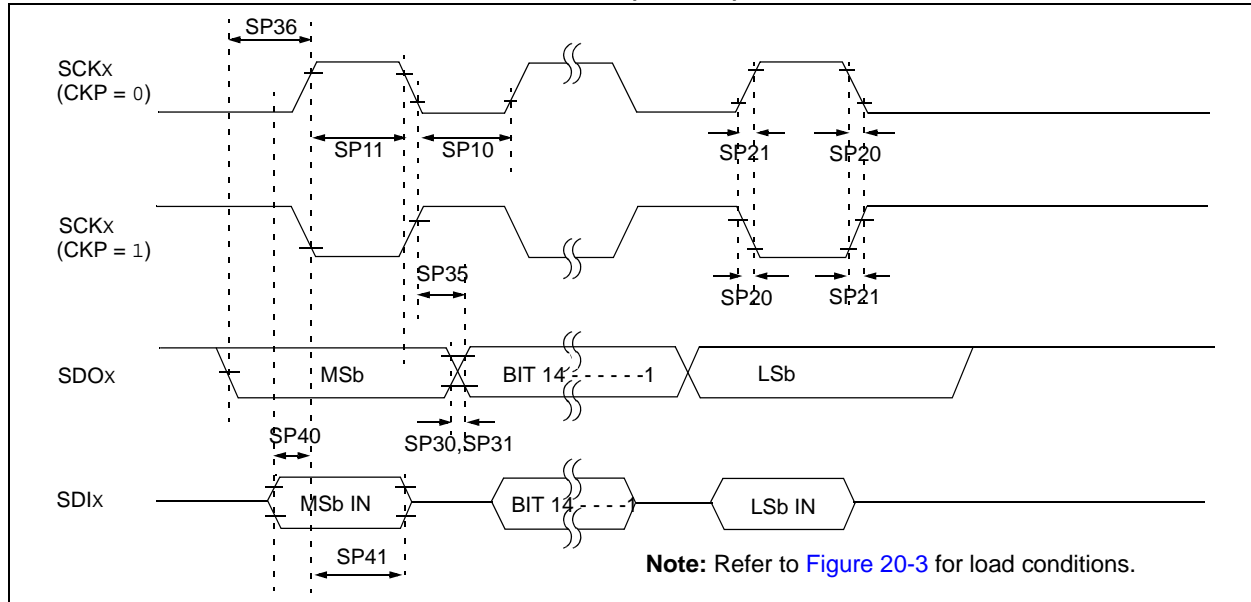


TABLE 20-30: SPI MODULE MASTER MODE (CKE = 1) TIMING REQUIREMENTS

| AC CHARACTERISTICS | | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤ TA ≤ +85°C for Industrial -40°C ≤ TA ≤ +125°C for Extended | | | | |
|--------------------|-----------------------|--|---|--------------------|-----|-------|--------------------|
| Param No. | Symbol | Characteristic ⁽¹⁾ | Min | Typ ⁽²⁾ | Max | Units | Conditions |
| SP10 | TscL | SCKx output low time ⁽³⁾ | TCY/2 | — | — | ns | — |
| SP11 | Tsch | SCKx output high time ⁽³⁾ | TCY/2 | — | — | ns | — |
| SP20 | TscF | SCKx output fall time ⁽⁴⁾ | — | — | — | ns | See parameter DO32 |
| SP21 | TscR | SCKx output rise time ⁽⁴⁾ | — | — | — | ns | See parameter DO31 |
| SP30 | TdoF | SDOx data output fall time ⁽⁴⁾ | — | — | — | ns | See parameter DO32 |
| SP31 | TdoR | SDOx data output rise time ⁽⁴⁾ | — | — | — | ns | See parameter DO31 |
| SP35 | Tsch2doV, TscL2doV | SDOx data output valid after SCKx edge | — | — | 30 | ns | — |
| SP36 | TdoV2sc, TdoV2scL | SDOx data output setup to first SCKx edge | 30 | — | — | ns | — |
| SP40 | TdiV2scH, TdiV2scL | Setup time of SDIx data input to SCKx edge | 20 | — | — | ns | — |
| SP41 | Tsch2diL, TscL2diL | Hold time of SDIx data input to SCKx edge | 20 | — | — | ns | — |

Note 1: These parameters are characterized but not tested in manufacturing.

2: Data in "Typ" column is at 5V, 25°C unless otherwise stated. Parameters are for design guidance only and are not tested.

3: The minimum clock period for SCK is 100 ns. Therefore, the clock generated in master mode must not violate this specification.

4: Assumes 50 pF load on all SPI pins.

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FIGURE 20-14: SPI MODULE SLAVE MODE (CKE = 0) TIMING CHARACTERISTICS

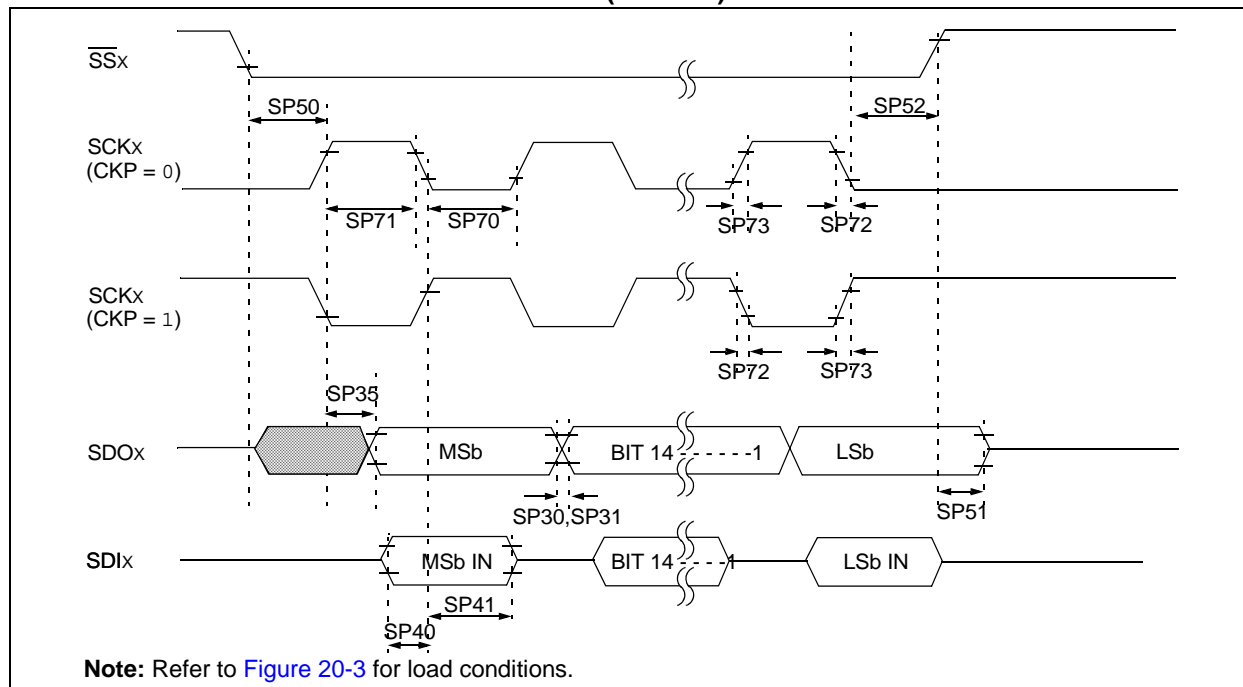


TABLE 20-31: SPI MODULE SLAVE MODE (CKE = 0) TIMING REQUIREMENTS

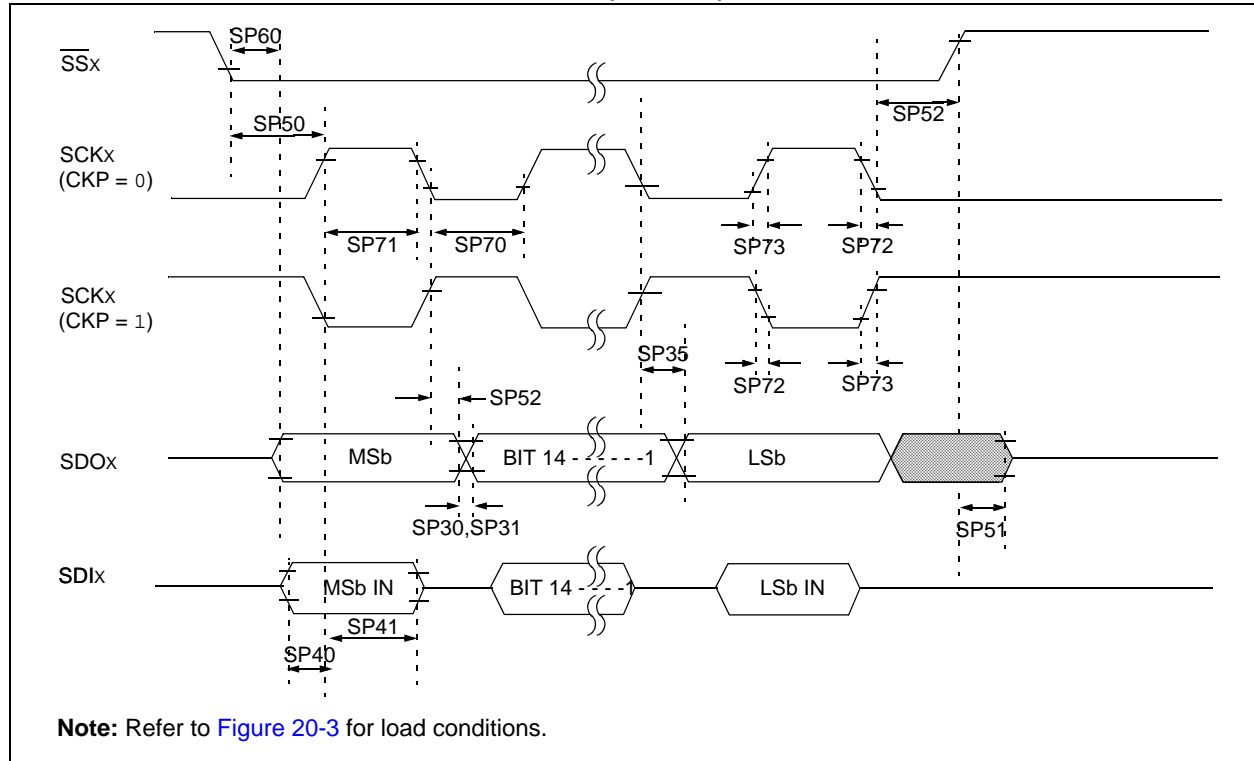
| AC CHARACTERISTICS | | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤ TA ≤ +85°C for Industrial -40°C ≤ TA ≤ +125°C for Extended | | | | |
|--------------------|-----------------------|---|---|--------------------|-----|-------|------------|
| Param No. | Symbol | Characteristic ⁽¹⁾ | Min | Typ ⁽²⁾ | Max | Units | Conditions |
| SP70 | TscL | SCKx Input Low Time | 30 | — | — | ns | — |
| SP71 | TscH | SCKx Input High Time | 30 | — | — | ns | — |
| SP72 | TscF | SCKx Input Fall Time ⁽³⁾ | — | 10 | 25 | ns | — |
| SP73 | TscR | SCKx Input Rise Time ⁽³⁾ | — | 10 | 25 | ns | — |
| SP30 | TdoF | SDOx Data Output Fall Time ⁽³⁾ | — | — | — | ns | See DO32 |
| SP31 | TdoR | SDOx Data Output Rise Time ⁽³⁾ | — | — | — | ns | See DO31 |
| SP35 | Tsch2doV, TscL2doV | SDOx Data Output Valid after SCKx Edge | — | — | 30 | ns | — |
| SP40 | TdiV2scH, TdiV2scL | Setup Time of SDIx Data Input to SCKx Edge | 20 | — | — | ns | — |
| SP41 | Tsch2diL, TscL2diL | Hold Time of SDIx Data Input to SCKx Edge | 20 | — | — | ns | — |
| SP50 | TssL2scH, TssL2scL | SSx↓ to SCKx↑ or SCKx↓ Input | 120 | — | — | ns | — |
| SP51 | TssH2doZ | SSx↑ to SDOx Output high impedance ⁽³⁾ | 10 | — | 50 | ns | — |
| SP52 | Tsch2ssH TscL2ssH | SSx after SCK Edge | 1.5 Tcy +40 | — | — | ns | — |

Note 1: These parameters are characterized but not tested in manufacturing.

Note 2: Data in "Typ" column is at 5V, 25°C unless otherwise stated. Parameters are for design guidance only and are not tested.

Note 3: Assumes 50 pF load on all SPI pins.

FIGURE 20-15: SPI MODULE SLAVE MODE (CKE = 1) TIMING CHARACTERISTICS



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TABLE 20-32: SPI MODULE SLAVE MODE (CKE = 1) TIMING REQUIREMENTS

| AC CHARACTERISTICS | | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤ TA ≤ +85°C for Industrial -40°C ≤ TA ≤ +125°C for Extended | | | | |
|--------------------|-----------------------|--|---|--------------------|-----|-------|--------------------|
| Param No. | Symbol | Characteristic ⁽¹⁾ | Min | Typ ⁽²⁾ | Max | Units | Conditions |
| SP70 | TscL | SCKx Input Low Time | 30 | — | — | ns | — |
| SP71 | TscH | SCKx Input High Time | 30 | — | — | ns | — |
| SP72 | TscF | SCKx Input Fall Time ⁽³⁾ | — | 10 | 25 | ns | — |
| SP73 | TscR | SCKx Input Rise Time ⁽³⁾ | — | 10 | 25 | ns | — |
| SP30 | TdoF | SDOx Data Output Fall Time ⁽³⁾ | — | — | — | ns | See parameter DO32 |
| SP31 | TdoR | SDOx Data Output Rise Time ⁽³⁾ | — | — | — | ns | See parameter DO31 |
| SP35 | Tsch2doV, TscL2doV | SDOx Data Output Valid after SCKx Edge | — | — | 30 | ns | — |
| SP40 | TdiV2sch, TdiV2scL | Setup Time of SDIx Data Input to SCKx Edge | 20 | — | — | ns | — |
| SP41 | Tsch2diL, TscL2diL | Hold Time of SDIx Data Input to SCKx Edge | 20 | — | — | ns | — |
| SP50 | TssL2sch, TssL2scL | $\overline{SS}x\downarrow$ to SCKx \downarrow or SCKx \uparrow input | 120 | — | — | ns | — |
| SP51 | TssH2doZ | $\overline{SS}x\uparrow$ to SDOx Output high impedance ⁽⁴⁾ | 10 | — | 50 | ns | — |
| SP52 | Tsch2ssH TscL2ssH | $\overline{SS}x\uparrow$ after SCKx Edge | 1.5 Tcy + 40 | — | — | ns | — |
| SP60 | TssL2doV | SDOx Data Output Valid after SCKx Edge | — | — | 50 | ns | — |

Note 1: These parameters are characterized but not tested in manufacturing.

2: Data in “Typ” column is at 5V, 25°C unless otherwise stated. Parameters are for design guidance only and are not tested.

3: The minimum clock period for SCK is 100 ns. Therefore, the clock generated in Master mode must not violate this specification.

4: Assumes 50 pF load on all SPI pins.

FIGURE 20-16: I²C™ BUS START/STOP BITS TIMING CHARACTERISTICS (MASTER MODE)

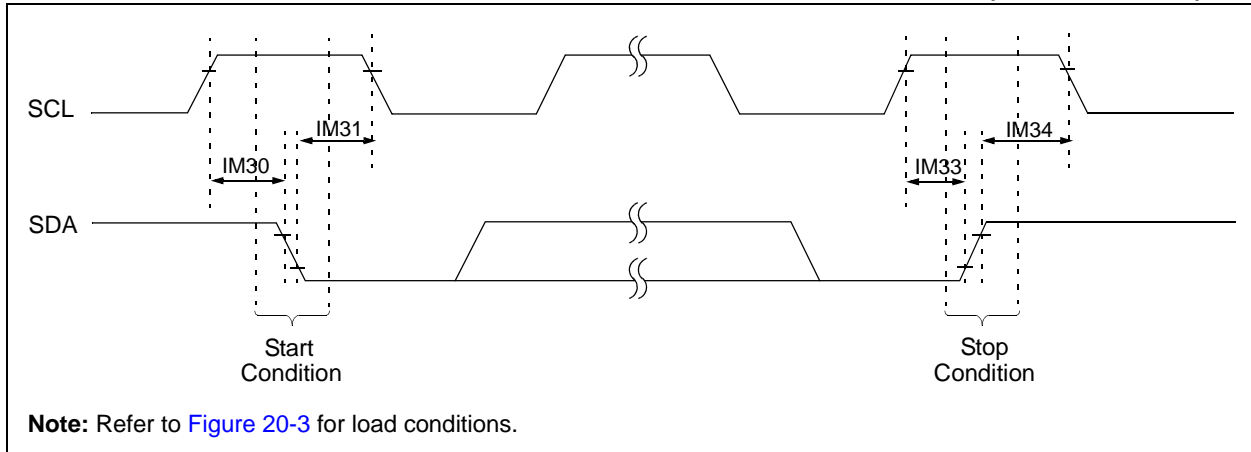
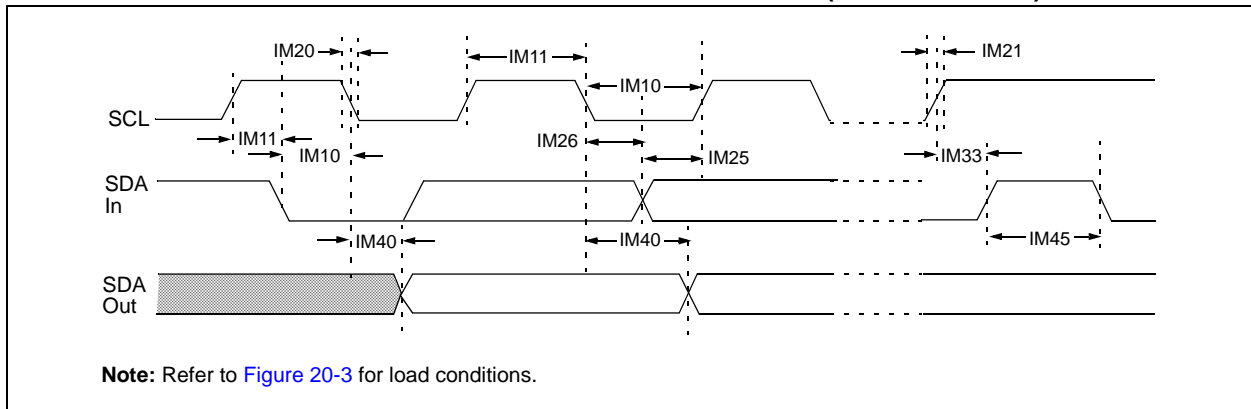


FIGURE 20-17: I²C™ BUS DATA TIMING CHARACTERISTICS (MASTER MODE)



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TABLE 20-33: I²C™ BUS DATA TIMING REQUIREMENTS (MASTER MODE)

| AC CHARACTERISTICS | | | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤ TA ≤ +85°C for Industrial -40°C ≤ TA ≤ +125°C for Extended | | | |
|--------------------|---------|----------------------------|---------------------------|---|------|-------|---|
| Param No. | Symbol | Characteristic | | Min ⁽¹⁾ | Max | Units | Conditions |
| IM10 | TLO:SCL | Clock Low Time | 100 kHz mode | Tcy/2 (BRG + 1) | — | μs | |
| | | | 400 kHz mode | Tcy/2 (BRG + 1) | — | μs | |
| | | | 1 MHz mode ⁽²⁾ | Tcy/2 (BRG + 1) | — | μs | |
| IM11 | THI:SCL | Clock High Time | 100 kHz mode | Tcy/2 (BRG + 1) | — | μs | |
| | | | 400 kHz mode | Tcy/2 (BRG + 1) | — | μs | |
| | | | 1 MHz mode ⁽²⁾ | Tcy/2 (BRG + 1) | — | μs | |
| IM20 | TF:SCL | SDA and SCL Fall Time | 100 kHz mode | — | 300 | ns | Cb is specified to be from 10 to 400 pF |
| | | | 400 kHz mode | 20 + 0.1 Cb | 300 | ns | |
| | | | 1 MHz mode ⁽²⁾ | — | 100 | ns | |
| IM21 | TR:SCL | SDA and SCL Rise Time | 100 kHz mode | — | 1000 | ns | Cb is specified to be from 10 to 400 pF |
| | | | 400 kHz mode | 20 + 0.1 Cb | 300 | ns | |
| | | | 1 MHz mode ⁽²⁾ | — | 300 | ns | |
| IM25 | TSU:DAT | Data Input Setup Time | 100 kHz mode | 250 | — | ns | |
| | | | 400 kHz mode | 100 | — | ns | |
| | | | 1 MHz mode ⁽²⁾ | — | — | ns | |
| IM26 | THD:DAT | Data Input Hold Time | 100 kHz mode | 0 | — | ns | |
| | | | 400 kHz mode | 0 | 0.9 | μs | |
| | | | 1 MHz mode ⁽²⁾ | — | — | ns | |
| IM30 | TSU:STA | Start Condition Setup Time | 100 kHz mode | Tcy/2 (BRG + 1) | — | μs | Only relevant for Repeated Start condition |
| | | | 400 kHz mode | Tcy/2 (BRG + 1) | — | μs | |
| | | | 1 MHz mode ⁽²⁾ | Tcy/2 (BRG + 1) | — | μs | |
| IM31 | THD:STA | Start Condition Hold Time | 100 kHz mode | Tcy/2 (BRG + 1) | — | μs | After this period the first clock pulse is generated |
| | | | 400 kHz mode | Tcy/2 (BRG + 1) | — | μs | |
| | | | 1 MHz mode ⁽²⁾ | Tcy/2 (BRG + 1) | — | μs | |
| IM33 | TSU:STO | Stop Condition Setup Time | 100 kHz mode | Tcy/2 (BRG + 1) | — | μs | |
| | | | 400 kHz mode | Tcy/2 (BRG + 1) | — | μs | |
| | | | 1 MHz mode ⁽²⁾ | Tcy/2 (BRG + 1) | — | μs | |
| IM34 | THD:STO | Stop Condition Hold Time | 100 kHz mode | Tcy/2 (BRG + 1) | — | ns | |
| | | | 400 kHz mode | Tcy/2 (BRG + 1) | — | ns | |
| | | | 1 MHz mode ⁽²⁾ | Tcy/2 (BRG + 1) | — | ns | |
| IM40 | TAA:SCL | Output Valid From Clock | 100 kHz mode | — | 3500 | ns | |
| | | | 400 kHz mode | — | 1000 | ns | |
| | | | 1 MHz mode ⁽²⁾ | — | — | ns | |
| IM45 | TBF:SDA | Bus Free Time | 100 kHz mode | 4.7 | — | μs | Time the bus must be free before a new transmission can start |
| | | | 400 kHz mode | 1.3 | — | μs | |
| | | | 1 MHz mode ⁽²⁾ | — | — | μs | |
| IM50 | CB | Bus Capacitive Loading | | — | 400 | pF | |

Note 1: BRG is the value of the I²C Baud Rate Generator. Refer to **Section 21. “Inter-Integrated Circuit™ (I²C)”** (DS70068) in the *dsPIC30F Family Reference Manual* (DS70046).

2: Maximum pin capacitance = 10 pF for all I²C™ pins (for 1 MHz mode only).

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FIGURE 20-18: I²C™ BUS START/STOP BITS TIMING CHARACTERISTICS (SLAVE MODE)

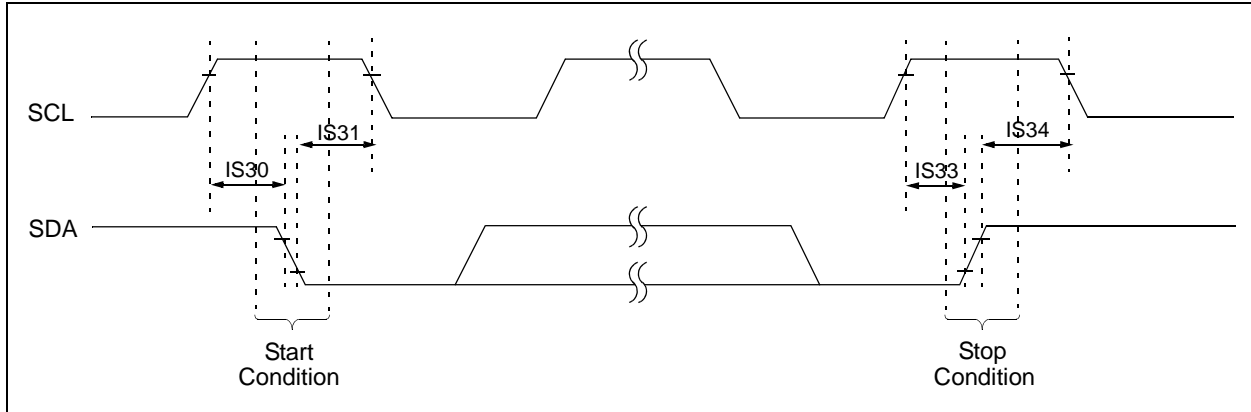


FIGURE 20-19: I²C™ BUS DATA TIMING CHARACTERISTICS (SLAVE MODE)

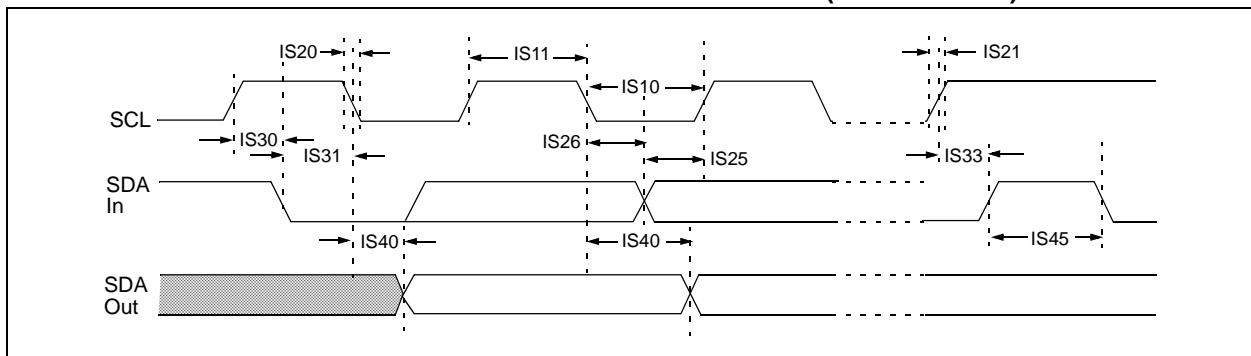


TABLE 20-34: I²C™ BUS DATA TIMING REQUIREMENTS (SLAVE MODE)

| AC CHARACTERISTICS | | | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤ T _A ≤ +85°C for Industrial -40°C ≤ T _A ≤ +125°C for Extended | | | |
|--------------------|---------|-----------------------|---------------------------|---|------|-------|---|
| Param No. | Symbol | Characteristic | | Min | Max | Units | Conditions |
| IS10 | TLO:SCL | Clock Low Time | 100 kHz mode | 4.7 | — | μs | Device must operate at a minimum of 1.5 MHz |
| | | | 400 kHz mode | 1.3 | — | μs | Device must operate at a minimum of 10 MHz. |
| | | | 1 MHz mode ⁽¹⁾ | 0.5 | — | μs | |
| IS11 | THI:SCL | Clock High Time | 100 kHz mode | 4.0 | — | μs | Device must operate at a minimum of 1.5 MHz |
| | | | 400 kHz mode | 0.6 | — | μs | Device must operate at a minimum of 10 MHz |
| | | | 1 MHz mode ⁽¹⁾ | 0.5 | — | μs | |
| IS20 | TF:SCL | SDA and SCL Fall Time | 100 kHz mode | — | 300 | ns | Cb is specified to be from 10 to 400 pF |
| | | | 400 kHz mode | 20 + 0.1 Cb | 300 | ns | |
| | | | 1 MHz mode ⁽¹⁾ | — | 100 | ns | |
| IS21 | TR:SCL | SDA and SCL Rise Time | 100 kHz mode | — | 1000 | ns | Cb is specified to be from 10 to 400 pF |
| | | | 400 kHz mode | 20 + 0.1 Cb | 300 | ns | |
| | | | 1 MHz mode ⁽¹⁾ | — | 300 | ns | |

Note 1: Maximum pin capacitance = 10 pF for all I²C™ pins (for 1 MHz mode only).

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TABLE 20-34: I²C™ BUS DATA TIMING REQUIREMENTS (SLAVE MODE) (CONTINUED)

| AC CHARACTERISTICS | | | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤T _A ≤+85°C for Industrial -40°C ≤T _A ≤+125°C for Extended | | | |
|--------------------|----------------------|----------------------------|---------------------------|---|------|-------|---|
| Param No. | Symbol | Characteristic | | Min | Max | Units | Conditions |
| IS25 | T _{SU} :DAT | Data Input Setup Time | 100 kHz mode | 250 | — | ns | |
| | | | 400 kHz mode | 100 | — | ns | |
| | | | 1 MHz mode ⁽¹⁾ | 100 | — | ns | |
| IS26 | T _{HD} :DAT | Data Input Hold Time | 100 kHz mode | 0 | — | ns | |
| | | | 400 kHz mode | 0 | 0.9 | μs | |
| | | | 1 MHz mode ⁽¹⁾ | 0 | 0.3 | μs | |
| IS30 | T _{SU} :STA | Start Condition Setup Time | 100 kHz mode | 4.7 | — | μs | Only relevant for Repeated Start condition |
| | | | 400 kHz mode | 0.6 | — | μs | |
| | | | 1 MHz mode ⁽¹⁾ | 0.25 | — | μs | |
| IS31 | T _{HD} :STA | Start Condition Hold Time | 100 kHz mode | 4.0 | — | μs | After this period the first clock pulse is generated |
| | | | 400 kHz mode | 0.6 | — | μs | |
| | | | 1 MHz mode ⁽¹⁾ | 0.25 | — | μs | |
| IS33 | T _{SU} :STO | Stop Condition Setup Time | 100 kHz mode | 4.7 | — | μs | |
| | | | 400 kHz mode | 0.6 | — | μs | |
| | | | 1 MHz mode ⁽¹⁾ | 0.6 | — | μs | |
| IS34 | T _{HD} :STO | Stop Condition Hold Time | 100 kHz mode | 4000 | — | ns | |
| | | | 400 kHz mode | 600 | — | ns | |
| | | | 1 MHz mode ⁽¹⁾ | 250 | — | ns | |
| IS40 | T _{AA} :SCL | Output Valid From Clock | 100 kHz mode | 0 | 3500 | ns | |
| | | | 400 kHz mode | 0 | 1000 | ns | |
| | | | 1 MHz mode ⁽¹⁾ | 0 | 350 | ns | |
| IS45 | T _{BF} :SDA | Bus Free Time | 100 kHz mode | 4.7 | — | μs | Time the bus must be free before a new transmission can start |
| | | | 400 kHz mode | 1.3 | — | μs | |
| | | | 1 MHz mode ⁽¹⁾ | 0.5 | — | μs | |
| IS50 | C _B | Bus Capacitive Loading | | — | 400 | pF | |

Note 1: Maximum pin capacitance = 10 pF for all I²C™ pins (for 1 MHz mode only).

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FIGURE 20-20: CAN MODULE I/O TIMING CHARACTERISTICS

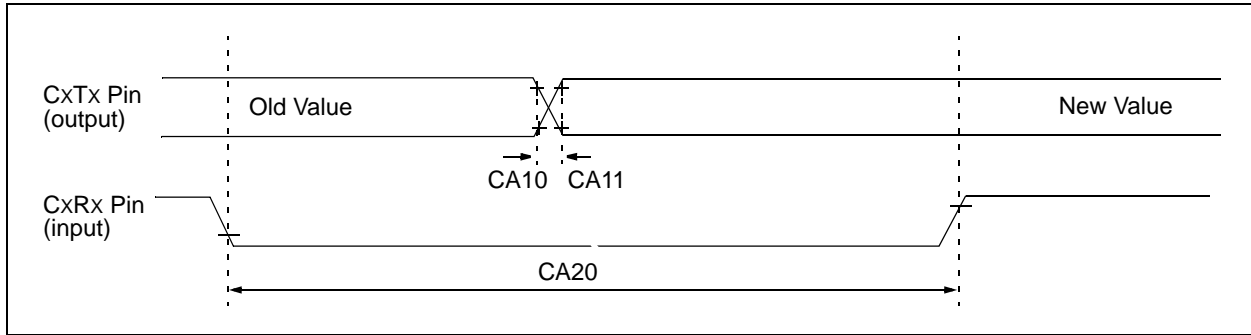


TABLE 20-35: CAN MODULE I/O TIMING REQUIREMENTS

| AC CHARACTERISTICS | | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature $-40^{\circ}\text{C} \leq T_A \leq +85^{\circ}\text{C}$ for Industrial $-40^{\circ}\text{C} \leq T_A \leq +125^{\circ}\text{C}$ for Extended | | | | |
|--------------------|--------|---|---|--------------------|-----|-------|------------|
| Param No. | Symbol | Characteristic ⁽¹⁾ | Min | Typ ⁽²⁾ | Max | Units | Conditions |
| CA10 | TioF | Port Output Fall Time | — | 10 | 25 | ns | |
| CA11 | TioR | Port Output Rise Time | — | 10 | 25 | ns | |
| CA20 | Tcwf | Pulse Width to Trigger CAN Wake-up Filter | 500 | — | — | ns | |

Note 1: These parameters are characterized but not tested in manufacturing.

2: Data in "Typ" column is at 5V, 25°C unless otherwise stated. Parameters are for design guidance only and are not tested.

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TABLE 20-36: 12-BIT ADC MODULE SPECIFICATIONS

| AC CHARACTERISTICS | | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤T _A ≤+85°C for Industrial -40°C ≤T _A ≤+125°C for Extended | | | | |
|----------------------------------|-----------|--|---|-------------|----------------------------|----------|--|
| Param No. | Symbol | Characteristic | Min. | Typ | Max. | Units | Conditions |
| Device Supply | | | | | | | |
| AD01 | AVDD | Module VDD Supply | Greater of VDD - 0.3 or 2.7 | — | Lesser of VDD + 0.3 or 5.5 | V | |
| AD02 | AVSS | Module VSS Supply | VSS - 0.3 | — | VSS + 0.3 | V | |
| Reference Inputs | | | | | | | |
| AD05 | VREFH | Reference Voltage High | AVSS + 2.7 | — | AVDD | V | |
| AD06 | VREFL | Reference Voltage Low | AVSS | — | AVDD - 2.7 | V | |
| AD07 | VREF | Absolute Reference Voltage | AVSS - 0.3 | — | AVDD + 0.3 | V | |
| AD08 | IREF | Current Drain | — | 200 .001 | 300 2 | μA μA | A/D operating A/D off |
| Analog Input | | | | | | | |
| AD10 | VINH-VINL | Full-Scale Input Span | VREFL | — | VREFH | V | See Note 1 |
| AD11 | VIN | Absolute Input Voltage | AVSS - 0.3 | — | AVDD + 0.3 | V | — |
| AD12 | — | Leakage Current | — | ±0.001 | ±0.610 | μA | VINL = AVSS = VREFL = 0V, AVDD = VREFH = 5V Source Impedance = 2.5 kΩ |
| AD13 | — | Leakage Current | — | ±0.001 | ±0.610 | μA | VINL = AVSS = VREFL = 0V, AVDD = VREFH = 3V Source Impedance = 2.5 kΩ |
| AD15 | RSS | Switch Resistance | — | 3.2K | — | Ω | |
| AD16 | CSAMPLE | Sample Capacitor | — | 18 | | pF | |
| AD17 | RIN | Recommended Impedance of Analog Voltage Source | — | — | 2.5K | Ω | |
| DC Accuracy⁽²⁾ | | | | | | | |
| AD20 | Nr | Resolution | 12 data bits | | | bits | |
| AD21 | INL | Integral Nonlinearity | — | — | <±1 | LSb | VINL = AVSS = VREFL = 0V, AVDD = VREFH = 5V |
| AD21A | INL | Integral Nonlinearity | — | — | <±1 | LSb | VINL = AVSS = VREFL = 0V, AVDD = VREFH = 3V |
| AD22 | DNL | Differential Nonlinearity | — | — | <±1 | LSb | VINL = AVSS = VREFL = 0V, AVDD = VREFH = 5V |
| AD22A | DNL | Differential Nonlinearity | — | — | <±1 | LSb | VINL = AVSS = VREFL = 0V, AVDD = VREFH = 3V |
| AD23 | GERR | Gain Error | +1.25 | +1.5 | +3 | LSb | VINL = AVSS = VREFL = 0V, AVDD = VREFH = 5V |
| AD23A | GERR | Gain Error | +1.25 | +1.5 | +3 | LSb | VINL = AVSS = VREFL = 0V, AVDD = VREFH = 3V |

Note 1: The A/D conversion result never decreases with an increase in the input voltage, and has no missing codes.

2: Measurements taken with external VREF+ and VREF- used as the ADC voltage references.

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TABLE 20-36: 12-BIT ADC MODULE SPECIFICATIONS (CONTINUED)

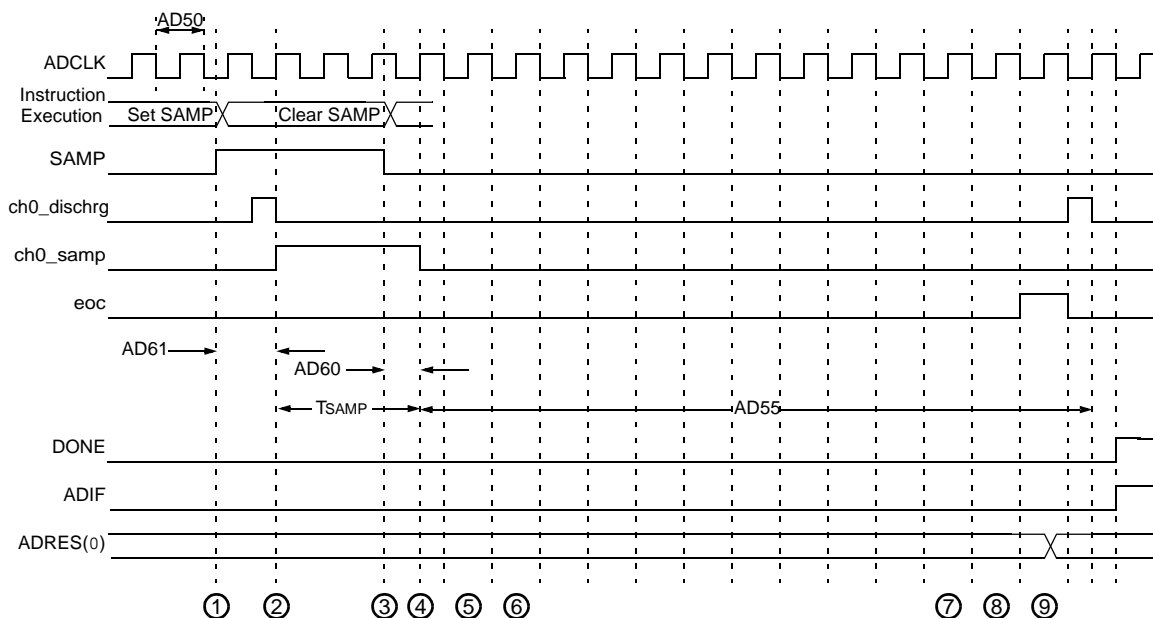
| AC CHARACTERISTICS | | | Standard Operating Conditions: 2.5V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤ TA ≤ +85°C for Industrial -40°C ≤ TA ≤ +125°C for Extended | | | | |
|---------------------|------------------|--------------------------------|---|------|-------|-------|---|
| Param No. | Symbol | Characteristic | Min. | Typ | Max. | Units | Conditions |
| AD24 | E _{OFF} | Offset Error | -2 | -1.5 | -1.25 | LSb | V _{INL} = AV _{SS} = V _{REFL} = 0V, AV _{DD} = V _{REFH} = 5V |
| AD24A | E _{OFF} | Offset Error | -2 | -1.5 | -1.25 | LSb | V _{INL} = AV _{SS} = V _{REFL} = 0V, AV _{DD} = V _{REFH} = 3V |
| AD25 | — | Monotonicity ⁽¹⁾ | — | — | — | — | Guaranteed |
| Dynamic Performance | | | | | | | |
| AD30 | THD | Total Harmonic Distortion | — | -71 | — | dB | |
| AD31 | SINAD | Signal to Noise and Distortion | — | 68 | — | dB | |
| AD32 | SFDR | Spurious Free Dynamic Range | — | 83 | — | dB | |
| AD33 | F _{NYQ} | Input Signal Bandwidth | — | — | 100 | kHz | |
| AD34 | ENOB | Effective Number of Bits | 10.95 | 11.1 | — | bits | |

Note 1: The A/D conversion result never decreases with an increase in the input voltage, and has no missing codes.

2: Measurements taken with external V_{REF+} and V_{REF-} used as the ADC voltage references.

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FIGURE 20-21: 12-BIT A/D CONVERSION TIMING CHARACTERISTICS
(ASAM = 0, SSRC = 000)



- ① - Software sets ADCON. SAMP to start sampling.
- ② - Sampling starts after discharge period.
TsAMP is described in **Section 18. "12-bit A/D Converter"** in the *dsPIC30F Family Reference Manual* (DS70046).
- ③ - Software clears ADCON. SAMP to Start conversion.
- ④ - Sampling ends, conversion sequence starts.
- ⑤ - Convert bit 11.
- ⑥ - Convert bit 10.
- ⑦ - Convert bit 1.
- ⑧ - Convert bit 0.
- ⑨ - One TAD for end of conversion.

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TABLE 20-37: 12-BIT A/D CONVERSION TIMING REQUIREMENTS

| AC CHARACTERISTICS | | | Standard Operating Conditions: 2.7V to 5.5V (unless otherwise stated) Operating temperature -40°C ≤ TA ≤ +85°C for Industrial -40°C ≤ TA ≤ +125°C for Extended | | | | |
|--------------------------|---------------------|---|---|---------|---------|-------|--|
| Param No. | Symbol | Characteristic | Min. | Typ | Max. | Units | Conditions |
| Clock Parameters | | | | | | | |
| AD50 | TAD | A/D Clock Period | 334 | — | — | ns | VDD = 3-5.5V (Note 1) |
| AD51 | tRC | A/D Internal RC Oscillator Period | 1.2 | 1.5 | 1.8 | μs | |
| Conversion Rate | | | | | | | |
| AD55 | tCONV | Conversion Time | — | 14 TAD | — | ns | |
| AD56a | FCNV | Throughput Rate | — | 200 | — | ksps | VDD = VREF = 5V, Industrial temperature |
| AD56b | FCNV | Throughput Rate | — | 100 | — | ksps | VDD = VREF = 5V, Extended temperature |
| AD57 | TSAMP | Sampling Time | 1 TAD | — | — | ns | VDD = 3-5.5V source resistance Rs = 0-2.5 kΩ |
| Timing Parameters | | | | | | | |
| AD60 | tPCS | Conversion Start from Sample Trigger | — | 1 TAD | — | ns | |
| AD61 | tPSS | Sample Start from Setting Sample (SAMP) Bit | 0.5 TAD | — | 1.5 TAD | ns | |
| AD62 | tCSS | Conversion Completion to Sample Start (ASAM = 1) | — | 0.5 TAD | — | ns | |
| AD63 | tDPU ⁽²⁾ | Time to Stabilize Analog Stage from A/D Off to A/D On | — | — | 20 | μs | |

Note 1: Because the sample caps will eventually lose charge, clock rates below 10 kHz can affect linearity performance, especially at elevated temperatures.

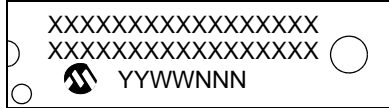
2: tDPU is the time required for the ADC module to stabilize when it is turned on (ADCON1<ADON> = 1). During this time the ADC result is indeterminate.

NOTES:

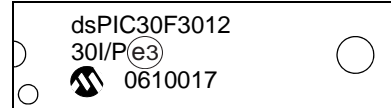
21.0 PACKAGING INFORMATION

21.1 Package Marking Information

18-Lead PDIP



Example



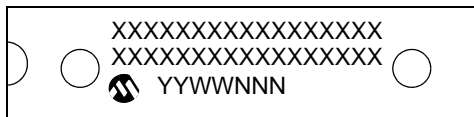
18-Lead SOIC



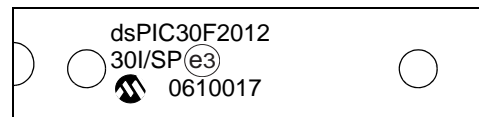
Example



28-Lead SPDIP



Example



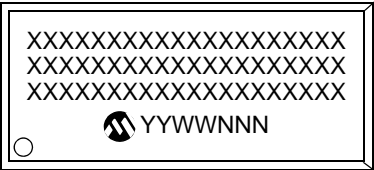
| | | |
|----------------|--------|--|
| Legend: | XX...X | Customer-specific information |
| | Y | Year code (last digit of calendar year) |
| | YY | Year code (last 2 digits of calendar year) |
| | WW | Week code (week of January 1 is week '01') |
| | NNN | Alphanumeric traceability code |
| | (e3) | Pb-free JEDEC designator for Matte Tin (Sn) |
| | * | This package is Pb-free. The Pb-free JEDEC designator (e3) can be found on the outer packaging for this package. |

Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information.

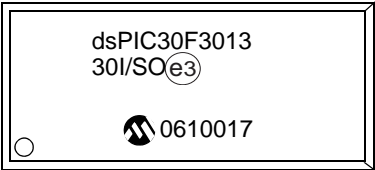
dsPIC30F2011/2012/3012/3013

21.2 Package Marking Information (Continued)

28-Lead SOIC



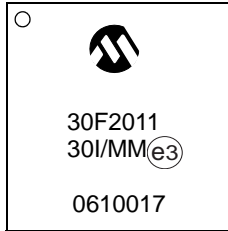
Example



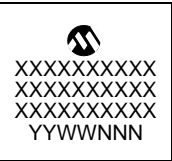
28-Lead QFN-S



Example



44-Lead QFN



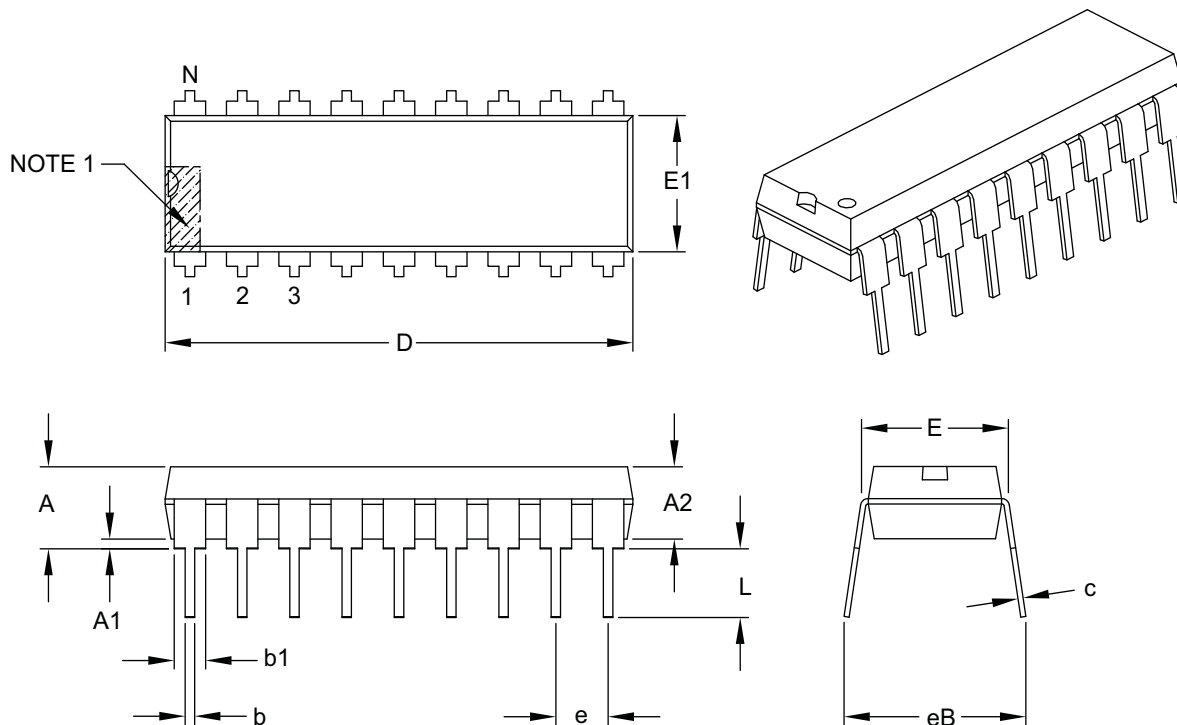
Example



dsPIC30F2011/2012/3012/3013

18-Lead Plastic Dual In-Line (P) – 300 mil Body [PDIP]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



| Units | | INCHES | | |
|----------------------------|----|----------|------|------|
| Dimension Limits | | MIN | NOM | MAX |
| Number of Pins | N | 18 | | |
| Pitch | e | .100 BSC | | |
| Top to Seating Plane | A | – | – | .210 |
| Molded Package Thickness | A2 | .115 | .130 | .195 |
| Base to Seating Plane | A1 | .015 | – | – |
| Shoulder to Shoulder Width | E | .300 | .310 | .325 |
| Molded Package Width | E1 | .240 | .250 | .280 |
| Overall Length | D | .880 | .900 | .920 |
| Tip to Seating Plane | L | .115 | .130 | .150 |
| Lead Thickness | c | .008 | .010 | .014 |
| Upper Lead Width | b1 | .045 | .060 | .070 |
| Lower Lead Width | b | .014 | .018 | .022 |
| Overall Row Spacing § | eB | – | – | .430 |

Notes:

- Pin 1 visual index feature may vary, but must be located within the hatched area.
- § Significant Characteristic.
- Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" per side.
- Dimensioning and tolerancing per ASME Y14.5M.

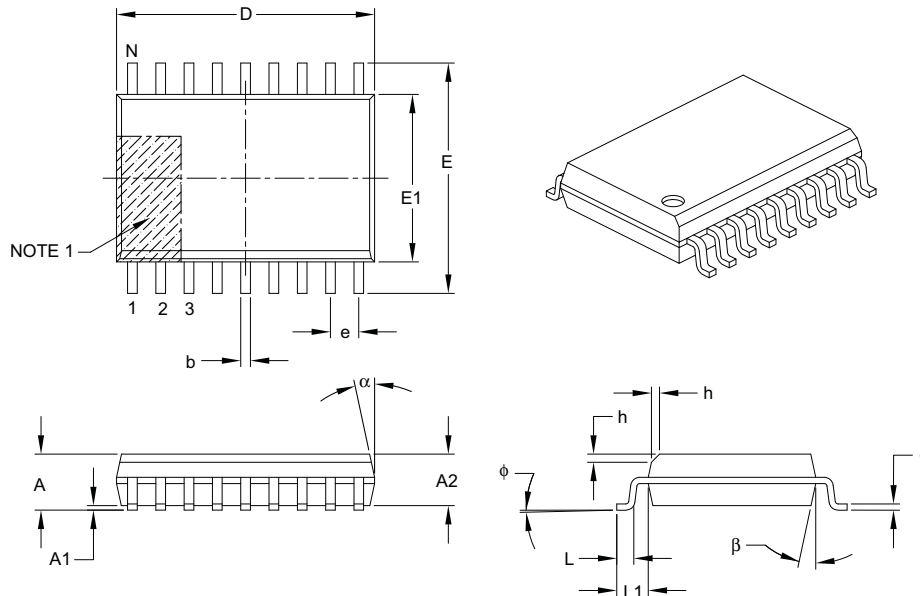
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing C04-007B

dsPIC30F2011/2012/3012/3013

18-Lead Plastic Small Outline (SO) – Wide, 7.50 mm Body [SOIC]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



| Units | | MILLIMETERS | | |
|--------------------------|----|-------------|-----|------|
| Dimension Limits | | MIN | NOM | MAX |
| Number of Pins | N | 18 | | |
| Pitch | e | 1.27 BSC | | |
| Overall Height | A | – | – | 2.65 |
| Molded Package Thickness | A2 | 2.05 | – | – |
| Standoff § | A1 | 0.10 | – | 0.30 |
| Overall Width | E | 10.30 BSC | | |
| Molded Package Width | E1 | 7.50 BSC | | |
| Overall Length | D | 11.55 BSC | | |
| Chamfer (optional) | h | 0.25 | – | 0.75 |
| Foot Length | L | 0.40 | – | 1.27 |
| Footprint | L1 | 1.40 REF | | |
| Foot Angle | φ | 0° | – | 8° |
| Lead Thickness | c | 0.20 | – | 0.33 |
| Lead Width | b | 0.31 | – | 0.51 |
| Mold Draft Angle Top | α | 5° | – | 15° |
| Mold Draft Angle Bottom | β | 5° | – | 15° |

Notes:

- Pin 1 visual index feature may vary, but must be located within the hatched area.
- § Significant Characteristic.
- Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15 mm per side.
- Dimensioning and tolerancing per ASME Y14.5M.

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

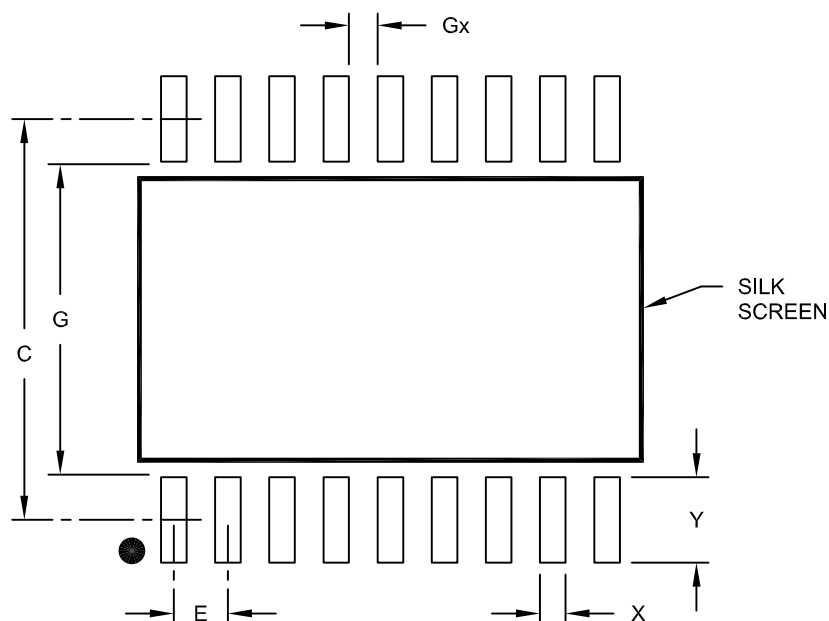
REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-051B

dsPIC30F2011/2012/3012/3013

18-Lead Plastic Small Outline (SO) - Wide, 7.50 mm Body [SOIC]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



RECOMMENDED LAND PATTERN

| Dimension Limits | Units | MILLIMETERS | | |
|-----------------------|-------|-------------|------|------|
| | | MIN | NOM | MAX |
| Contact Pitch | E | 1.27 BSC | | |
| Contact Pad Spacing | C | | 9.40 | |
| Contact Pad Width | X | | | 0.60 |
| Contact Pad Length | Y | | | 2.00 |
| Distance Between Pads | Gx | 0.67 | | |
| Distance Between Pads | G | 7.40 | | |

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

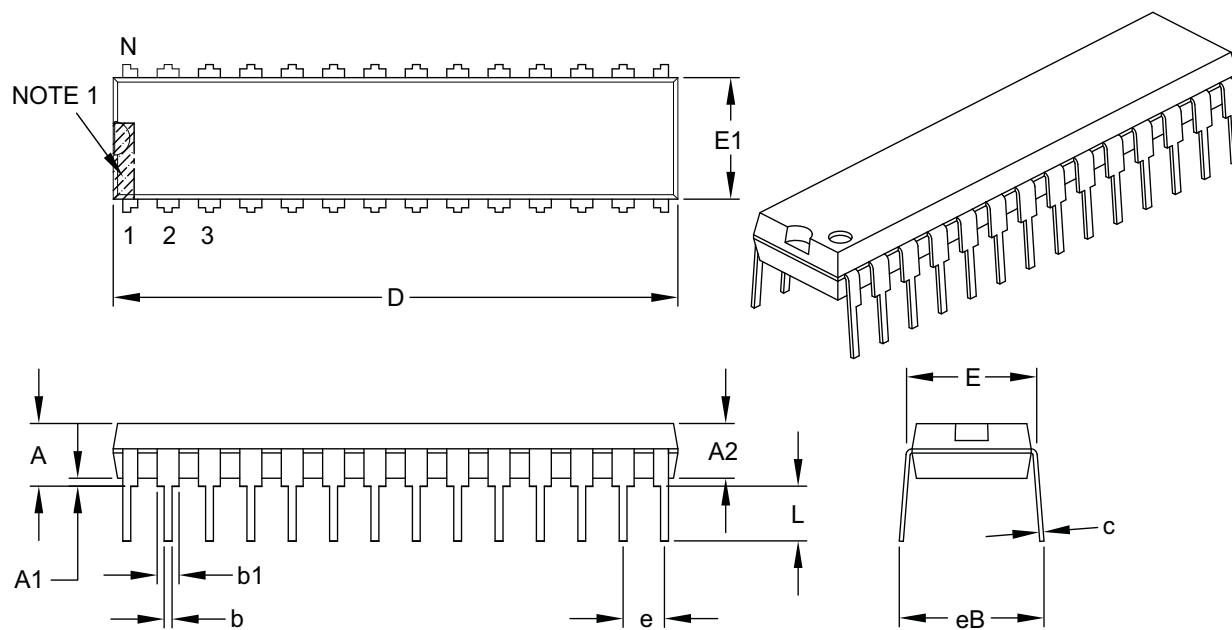
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing No. C04-2051A

dsPIC30F2011/2012/3012/3013

28-Lead Skinny Plastic Dual In-Line (SP) – 300 mil Body [SPDIP]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



| | | Units | INCHES | | |
|----------------------------|----|-------|----------|-------|-------|
| Dimension Limits | | | MIN | NOM | MAX |
| Number of Pins | N | | 28 | | |
| Pitch | e | | .100 BSC | | |
| Top to Seating Plane | A | | – | – | .200 |
| Molded Package Thickness | A2 | | .120 | .135 | .150 |
| Base to Seating Plane | A1 | | .015 | – | – |
| Shoulder to Shoulder Width | E | | .290 | .310 | .335 |
| Molded Package Width | E1 | | .240 | .285 | .295 |
| Overall Length | D | | 1.345 | 1.365 | 1.400 |
| Tip to Seating Plane | L | | .110 | .130 | .150 |
| Lead Thickness | c | | .008 | .010 | .015 |
| Upper Lead Width | b1 | | .040 | .050 | .070 |
| Lower Lead Width | b | | .014 | .018 | .022 |
| Overall Row Spacing § | eB | | – | – | .430 |

Notes:

- Pin 1 visual index feature may vary, but must be located within the hatched area.
- § Significant Characteristic.
- Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" per side.
- Dimensioning and tolerancing per ASME Y14.5M.

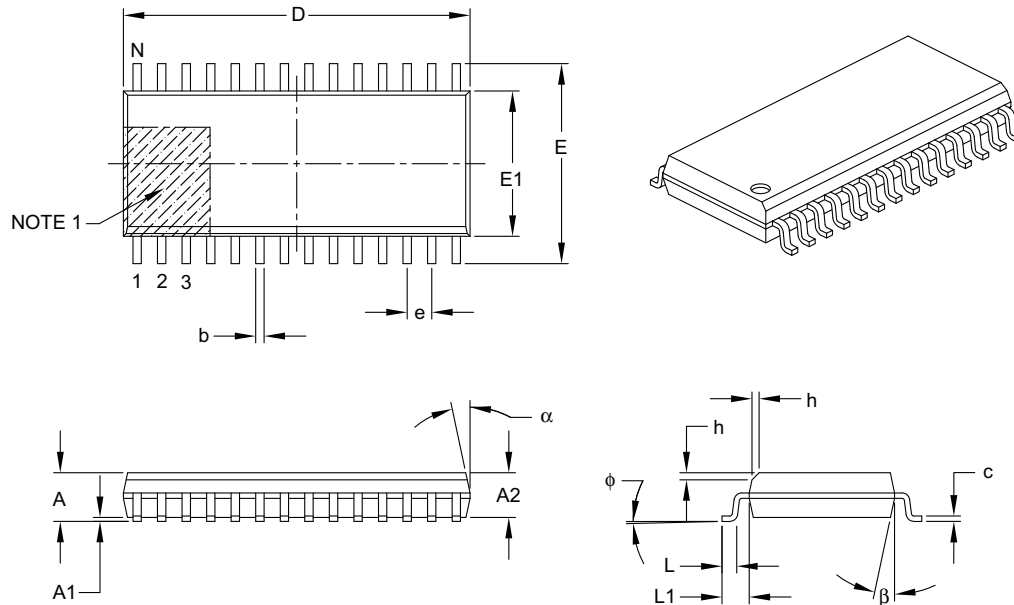
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing C04-070B

dsPIC30F2011/2012/3012/3013

28-Lead Plastic Small Outline (SO) – Wide, 7.50 mm Body [SOIC]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



| Units | | MILLIMETERS | | |
|--------------------------|----|-------------|-----|------|
| Dimension Limits | | MIN | NOM | MAX |
| Number of Pins | N | 28 | | |
| Pitch | e | 1.27 BSC | | |
| Overall Height | A | – | – | 2.65 |
| Molded Package Thickness | A2 | 2.05 | – | – |
| Standoff § | A1 | 0.10 | – | 0.30 |
| Overall Width | E | 10.30 BSC | | |
| Molded Package Width | E1 | 7.50 BSC | | |
| Overall Length | D | 17.90 BSC | | |
| Chamfer (optional) | h | 0.25 | – | 0.75 |
| Foot Length | L | 0.40 | – | 1.27 |
| Footprint | L1 | 1.40 REF | | |
| Foot Angle Top | φ | 0° | – | 8° |
| Lead Thickness | c | 0.18 | – | 0.33 |
| Lead Width | b | 0.31 | – | 0.51 |
| Mold Draft Angle Top | α | 5° | – | 15° |
| Mold Draft Angle Bottom | β | 5° | – | 15° |

Notes:

- Pin 1 visual index feature may vary, but must be located within the hatched area.
- § Significant Characteristic.
- Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15 mm per side.
- Dimensioning and tolerancing per ASME Y14.5M.

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

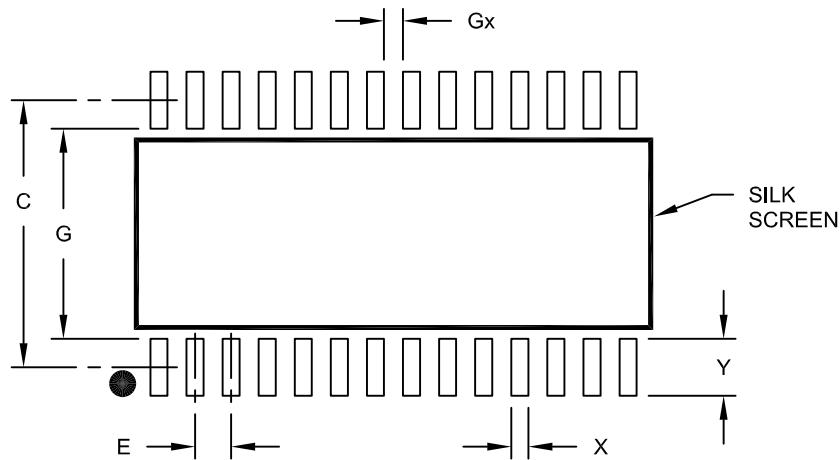
REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-052B

dsPIC30F2011/2012/3012/3013

28-Lead Plastic Small Outline (SO) - Wide, 7.50 mm Body [SOIC]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



RECOMMENDED LAND PATTERN

| Units | | MILLIMETERS | | |
|--------------------------|----|-------------|----------|------|
| Dimension Limits | | MIN | NOM | MAX |
| Contact Pitch | E | | 1.27 BSC | |
| Contact Pad Spacing | C | | 9.40 | |
| Contact Pad Width (X28) | X | | | 0.60 |
| Contact Pad Length (X28) | Y | | | 2.00 |
| Distance Between Pads | Gx | 0.67 | | |
| Distance Between Pads | G | 7.40 | | |

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

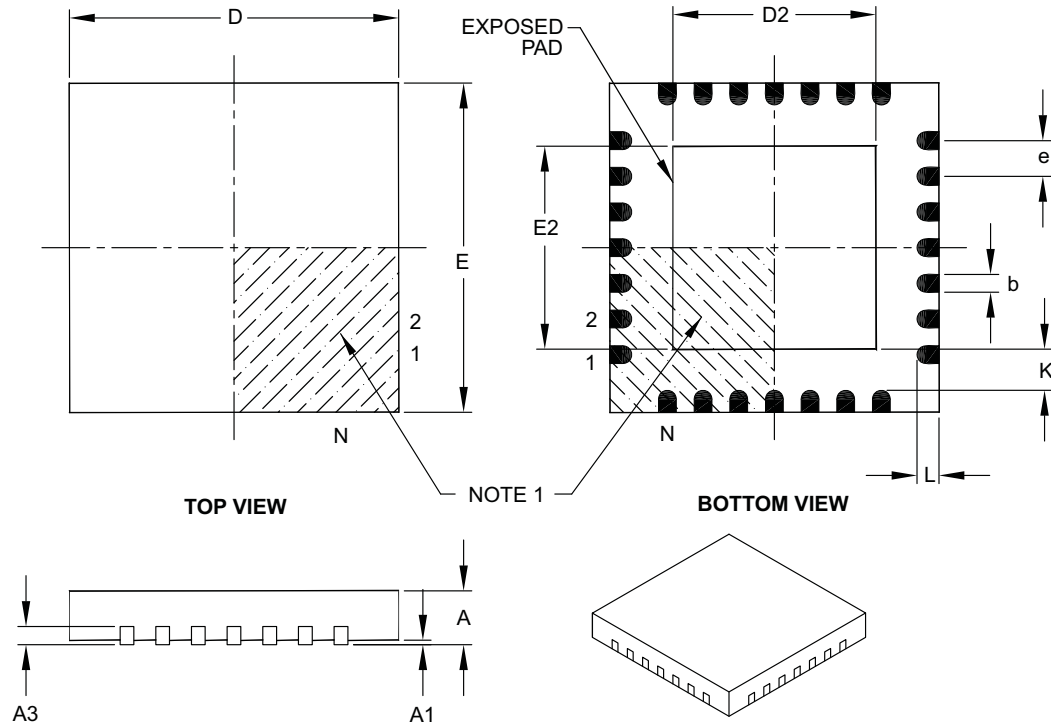
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing No. C04-2052A

dsPIC30F2011/2012/3012/3013

28-Lead Plastic Quad Flat, No Lead Package (MM) – 6x6x0.9 mm Body [QFN-S] with 0.40 mm Contact Length

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



| Units | | MILLIMETERS | | |
|------------------------|----|-------------|------|------|
| Dimension Limits | | MIN | NOM | MAX |
| Number of Pins | N | 28 | | |
| Pitch | e | 0.65 BSC | | |
| Overall Height | A | 0.80 | 0.90 | 1.00 |
| Standoff | A1 | 0.00 | 0.02 | 0.05 |
| Contact Thickness | A3 | 0.20 REF | | |
| Overall Width | E | 6.00 BSC | | |
| Exposed Pad Width | E2 | 3.65 | 3.70 | 4.70 |
| Overall Length | D | 6.00 BSC | | |
| Exposed Pad Length | D2 | 3.65 | 3.70 | 4.70 |
| Contact Width | b | 0.23 | 0.38 | 0.43 |
| Contact Length | L | 0.30 | 0.40 | 0.50 |
| Contact-to-Exposed Pad | K | 0.20 | — | — |

Notes:

- Pin 1 visual index feature may vary, but must be located within the hatched area.
- Package is saw singulated.
- Dimensioning and tolerancing per ASME Y14.5M.

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

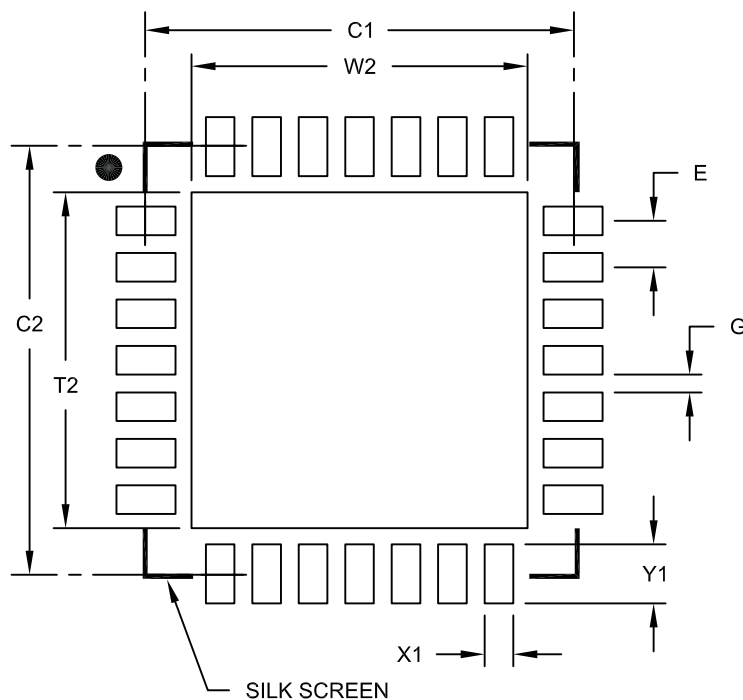
REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-124B

dsPIC30F2011/2012/3012/3013

28-Lead Plastic Quad Flat, No Lead Package (MM) – 6x6x0.9 mm Body [QFN-S] with 0.40 mm Contact Length

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



RECOMMENDED LAND PATTERN

| Units | | MILLIMETERS | | |
|----------------------------|----|-------------|------|------|
| Dimension Limits | | MIN | NOM | MAX |
| Contact Pitch | E | 0.65 BSC | | |
| Optional Center Pad Width | W2 | | | 4.70 |
| Optional Center Pad Length | T2 | | | 4.70 |
| Contact Pad Spacing | C1 | | 6.00 | |
| Contact Pad Spacing | C2 | | 6.00 | |
| Contact Pad Width (X28) | X1 | | | 0.40 |
| Contact Pad Length (X28) | Y1 | | | 0.85 |
| Distance Between Pads | G | 0.25 | | |

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

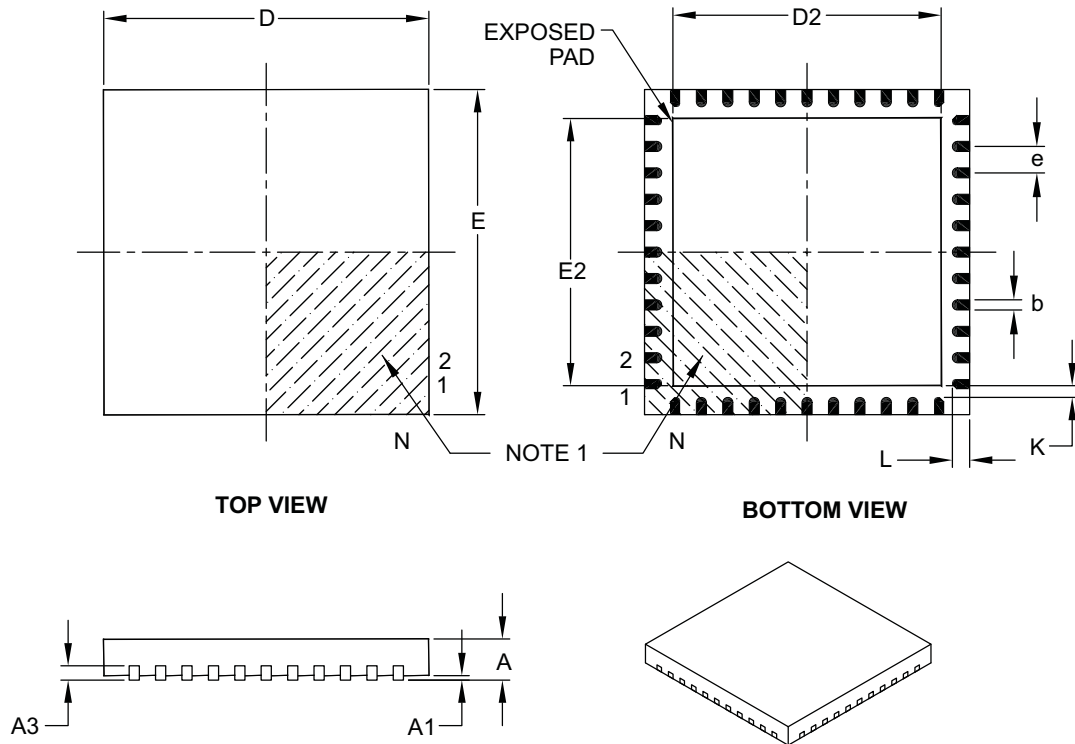
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing No. C04-2124A

dsPIC30F2011/2012/3012/3013

44-Lead Plastic Quad Flat, No Lead Package (ML) – 8x8 mm Body [QFN]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



| Units | | MILLIMETERS | | |
|------------------------|----|-------------|------|------|
| Dimension Limits | | MIN | NOM | MAX |
| Number of Pins | N | 44 | | |
| Pitch | e | 0.65 BSC | | |
| Overall Height | A | 0.80 | 0.90 | 1.00 |
| Standoff | A1 | 0.00 | 0.02 | 0.05 |
| Contact Thickness | A3 | 0.20 REF | | |
| Overall Width | E | 8.00 BSC | | |
| Exposed Pad Width | E2 | 6.30 | 6.45 | 6.80 |
| Overall Length | D | 8.00 BSC | | |
| Exposed Pad Length | D2 | 6.30 | 6.45 | 6.80 |
| Contact Width | b | 0.25 | 0.30 | 0.38 |
| Contact Length | L | 0.30 | 0.40 | 0.50 |
| Contact-to-Exposed Pad | K | 0.20 | — | — |

Notes:

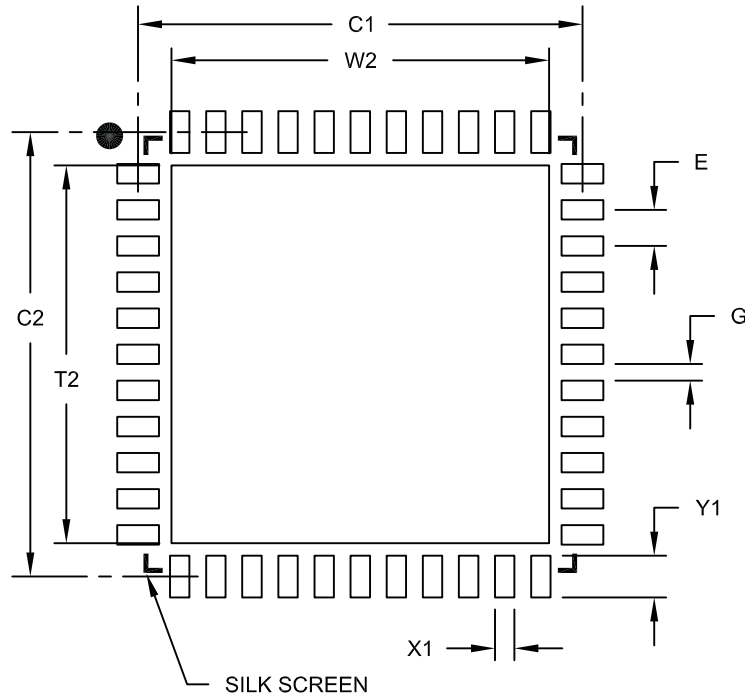
- Pin 1 visual index feature may vary, but must be located within the hatched area.
- Package is saw singulated.
- Dimensioning and tolerancing per ASME Y14.5M.
 - BSC: Basic Dimension. Theoretically exact value shown without tolerances.
 - REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-103B

dsPIC30F2011/2012/3012/3013

44-Lead Plastic Quad Flat, No Lead Package (ML) – 8x8 mm Body [QFN]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



RECOMMENDED LAND PATTERN

| Units | | MILLIMETERS | | |
|----------------------------|----|-------------|----------|------|
| Dimension Limits | | MIN | NOM | MAX |
| Contact Pitch | E | | 0.65 BSC | |
| Optional Center Pad Width | W2 | | | 6.80 |
| Optional Center Pad Length | T2 | | | 6.80 |
| Contact Pad Spacing | C1 | | 8.00 | |
| Contact Pad Spacing | C2 | | 8.00 | |
| Contact Pad Width (X44) | X1 | | | 0.35 |
| Contact Pad Length (X44) | Y1 | | | 0.80 |
| Distance Between Pads | G | 0.25 | | |

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing No. C04-2103A

APPENDIX A: REVISION HISTORY

Revision D (August 2006)

Previous versions of this data sheet contained Advance or Preliminary Information. They were distributed with incomplete characterization data.

This revision reflects these updates:

- Supported I²C Slave Addresses (see [Table 14-1](#))
- ADC Conversion Clock selection to allow 200 kHz sampling rate (see [Section 16.0 “12-bit Analog-to-Digital Converter \(ADC\) Module”](#))
- Operating Current (IDD) Specifications (see [Table 20-5](#))
- Idle Current (I_{IDLE}) Specifications (see [Table 20-6](#))
- Power-Down Current (I_{PD}) Specifications (see [Table 20-7](#))
- I/O pin Input Specifications (see [Table 20-8](#))
- BOR voltage limits (see [Table 20-11](#))
- Watchdog Timer time-out limits (see [Table 20-21](#))

Revision E (December 2006)

This revision includes updates to the packaging diagrams.

Revision F (May 2008)

This revision reflects these updates:

- Added FUSE Configuration Register (FICD) details (see [Section 17.7 “Device Configuration Registers”](#) and [Table 17-8](#))
- Added Note 2 to Device Configuration Registers table ([Table 17-8](#))
- Updated Bit 10 in the UART2 Register Map (see [Table 15-2](#)). This bit is unimplemented.
- Electrical Specifications:
 - Resolved TBD values for parameters DO10, DO16, DO20, and DO26 (see [Table 20-9](#))
 - 10-bit High-Speed ADC t_{PDU} timing parameter (time to stabilize) has been updated from 20 μs typical to 20 μs maximum (see [Table 20-37](#))
 - Parameter OS65 (Internal RC Accuracy) has been expanded to reflect multiple Min and Max values for different temperatures (see [Table 20-19](#))
 - Parameter DC12 (RAM Data Retention Voltage) has been updated to include a Min value (see [Table 20-4](#))
 - Parameter D134 (Erase/Write Cycle Time) has been updated to include Min and Max values and the Typ value has been removed (see [Table 20-12](#))
 - Removed parameters OS62 (Internal FRC Jitter) and OS64 (Internal FRC Drift) and Note 2 from AC Characteristics (see [Table 20-18](#))
 - Parameter OS63 (Internal FRC Accuracy) has been expanded to reflect multiple Min and Max values for different temperatures (see [Table 20-18](#))
 - Updated Min and Max values and Conditions for parameter SY11 and updated Min, Typ, and Max values and Conditions for parameter SY20 (see [Table 20-21](#))
- Additional minor corrections throughout the document

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Revision G (November 2010)

This revision includes minor typographical and formatting changes throughout the data sheet text.

The major changes are referenced by their respective section in [Table A-1](#).

TABLE A-1: MAJOR SECTION UPDATES

| Section Name | Update Description |
|---|--|
| “High-Performance, 16-Bit Digital Signal Controllers” | Added Note 1 to all QFN pin diagrams (see “Pin Diagrams”). |
| Section 1.0 “Device Overview” | Updated the Pinout I/O Descriptions for AVDD and AVSS (see Table 1-1). |
| Section 17.0 “System Integration” | Added a shaded note on OSC1UN functionality in Section 17.2.5 “Fast RC Oscillator (FRC)” . |
| Section 20.0 “Electrical Characteristics” | <p>Updated the maximum value for parameter DI19 and the minimum value for parameter DI29 in the I/O Pin Input Specifications (see Table 20-8).</p> <p>Removed parameter D136 and updated the minimum, typical, maximum, and conditions for parameters D122 and D134 in the Program and EEPROM specifications (see Table 20-12).</p> <p>Renamed parameter AD56 to AD56a and added parameter AD56b to the 12-bit A/D Conversion Timing Requirements (see Table 20-37).</p> |
| “Product Identification System” | Added the “MM” package definition. |

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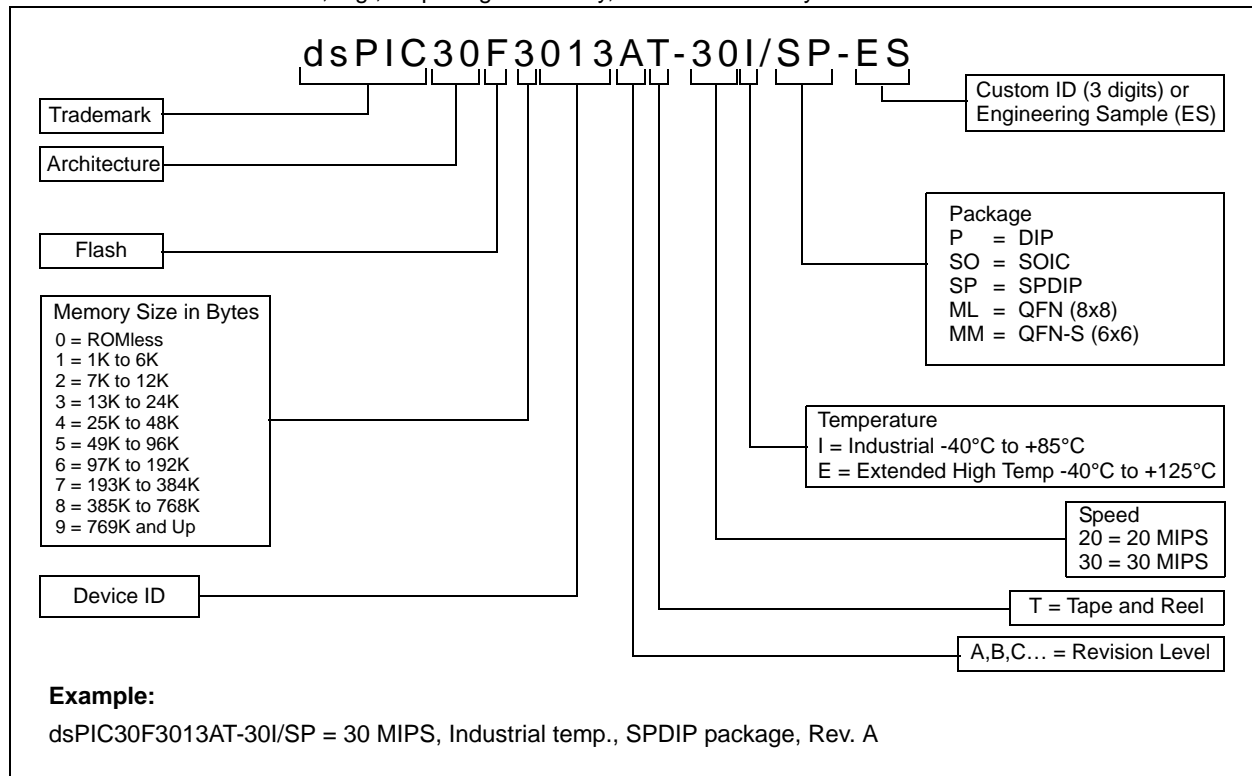
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